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EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 18, 1901.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

Mr. Herbert Thomas Burls, F.G.S., was elected to the Ordinary Membership of the Society.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 18, 1901.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

Fifteen Members were present. The election of Mr. H. T. Burls as an Ordinary Member was confirmed.

The following papers were read:—

1. On the anharmonic ratio of four faces in a zone: by Mr. Alfred Harker.

2. On the arrangement of the chemical atoms in potassium-alum, and in some of the bodies which display tetartohedral symmetry: by Mr. W. Barlow.

3. Remarks on the crystallography of Calaverite: by Mr. G. F. Herbert Smith (p. 122).

4. On pseudomorphous calcium carbonate from the Clyde-bed: by Dr. C. O. Trechmann.

5. On some inter-relations of species, especially sulphates and phosphates: by Mr. G. T. Prior.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 12, 1901.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

The deaths of Baron Nordenskiöld, Honorary Member, Dr. Moberg, and Mr. W. Terrill, Ordinary Members, were announced.

The Foreign Secretary was requested to send a letter of congratulation to Professor Groth on the completion of the twenty-fifth year of the publication of the *Zeitschrift für Krystallographie.*

The following dates were selected for the meetings of the Society during 1902:—February 4, March 25, June 24, and November 18, the last to be the Anniversary Meeting.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 12, 1901.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

Nineteen Members and one visitor were present.

The scrutineers reported that forty voting papers had been returned, and that the following had been elected Officers and Members of Council for the year 1901–2 :—

President. Hugo Müller, Esq., Ph.D., F.R.S.
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The following Report of Council for the year 1900–1 was read by the General Secretary.

ANNUAL REPORT.

The Balance Sheet for the year ending December 31, 1900, which was issued with Number 59 of the Journal, showed that the Assets of the Society (exclusive of the Library and the Stock of the Journal) amounted to £645 6*s.* 5*d.*, and that the Liabilities amounted to £59 18*s.* 1*d.* The number of actual Members, who had compounded before December 31, 1900, for the payment of their Annual Subscription, was fifty-two; the value of the Stock invested in the names of the Trustees of the Society was on that date £505 9*s.* 7*d.*

During the Session 1900–1 the Society has lost three Ordinary Members and one Honorary Member by death, and two Ordinary Members by resignation; on the other hand, two Ordinary Members

have been elected. The total number of members is now 121; of these 102 are Ordinary Members and nineteen are Honorary Members.

Four meetings have been held during the year, all in London and (by kind permission) in the apartments of the Geological Society, Burlington House.

Two Numbers of the Journal, No. 58 published in November, 1900, and No. 59 published in May, 1901, have been issued since the last Anniversary Meeting. The papers therein contained differ widely in character. On the instrumental side of crystallographic science, Mr. Herbert Smith has described an improved form of his three-circle goniometer. To the mathematical side of crystallography and optics contributions have been made by Professor Lewis, Mr. Hudson, Mr. Hilton and Mr. Harker. On the physical side, Mr. Bowman has given an account of a method of demonstrating the variation of thermal conductivity with crystallographic direction. To our knowledge of various mineral species additions have been made in papers by Mr. Spencer, on Marshite, Miersite, Iodyrite and Stannite, by Professor Lewis and Mr. Hall on Copper-pyrites, by Mr. Solly on Rathite, by Mr. Bowman on Pyroxene and Sapphire, by Miss Kelly on calcium carbonate. Information relative to topographical mineralogy has been given by Mr. Bowman and Dr. Trechmann. Chemical mineralogy is represented by a paper of Dr. Evans on the alteration of Iron-pyrites by underground water. Petrography is illustrated by two papers of Mr. Prior. Mr. Fletcher has given a detailed report on the circumstances of the fall and on the characters of the meteoric stones of Mount Zomba. Mr. Spencer has supplied a useful list of new Mineral Names and an Index to Volume XII of the Journal.

For the convenience of the Members, the new Bye-Laws, a list of the Members, and a list of the Serials in the Library, have been issued as part of the first Number of the current Volume of the Journal.

The Society is deeply indebted to the President, Professor Church, for the gift of (1) various volumes of the Journal of the Mineralogical Society of France, (2) the sum of ten pounds for expenditure in binding and (3) a beautifully bound Obligation-Book for the preservation of the autographs of the Members.

The Council has to congratulate the Society on its scientific prosperity.

On the motion of the President, seconded by the General Secretary, the Report was adopted. A vote of thanks to the Geological Society for the use of its apartments was carried by acclamation.

The following papers were then read:—

1. On Baumhauerite, a new mineral, Dufrenoysite and Hyalophane, from the Binnenthal: by Mr. R. H. Solly (p. 151).

2. On Gibbsite from the Palni Hills in Southern India: by Dr. H. Warth (communicated by Mr. Mallet) (p. 172).

3. On the occurrence of Gold in the Klondike: results of a visit in 1901: by Professor Miers.

The papers were illustrated by specimens, and Professor Miers showed a series of lantern-slides prepared from photographs taken by him at Klondike.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, February 4, 1902.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Mr. George Duncan McGrigor, F.R.G.S., was elected an Ordinary Member of the Society. The resignation of Mr. H. M. Platnauer, Ordinary Member, was announced.

GENERAL MEETING.

Held in the Apartments of the Geological Society, February 4, 1902.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Fifteen members were present. The election of Mr. G. D. McGrigor as an Ordinary Member was confirmed.

The following papers were read:—

1. On the Hornsilvers: by Messrs. G. T. Prior and L. J. Spencer (p. 174).

2. The identity of Kilbrickenite with Geocronite: Analyses of Miersite, Marshite and Copper-pyrites: by Mr. G. T. Prior (p. 186).

3. A new Sapphirine-like mineral from Ceylon: by Messrs. G. T. Prior and A. K. Coomára-Swámy.

4. Attempts to reproduce interference-effects by three-colour printing: by Professor Miers.

Specimens illustrative of the above papers were shown by Mr. Coomára-Swámy and Professor Miers; the latter further exhibited twin-crystals of calcite according to the less common twin-plane ($11\bar{1}$) from a new locality in Somersetshire, and also some crystalline gold-nuggets from Klondike.

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No. 60. MAY, 1902. Vol. XIII.

COMMUNICATIONS FROM THE OXFORD MINERALOGICAL LABORATORY.

On an Occurrence of Minerals at Haddam Neck, Connecticut, U.S.A.

By H. L. BOWMAN, M.A.
Demonstrator in Mineralogy.

(With Plate IV.)

[Read March 19, 1901.]

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IN the summer of 1896 the Oxford Museum was enriched by a fine series of about eighty mineral specimens from a newly opened quarry at Haddam Neck in Connecticut, which were kindly presented by Mr. Ernest Schernikow of New York.

The species included in the series are green and pink tourmaline, albite, microcline, green and pink apatite, brown fluor, beryl, quartz,

cookeite, lilac lepidolite, greenish-white muscovite, and a peculiar pink fibrous variety of the same mineral. To these must also be added, as occurring at the same place, green fluor, microlite, and columbite.

The locality is described as Haddam Neck, a village opposite to Haddam, on the other (eastern) bank of the Connecticut River, which is here about half a mile wide.

Mr. Schernikow gives the following account of the occurrence:—'The deposit is what I would call a vein of very coarse granite—that is, the quartz, felspar, and mica are in very large pieces. Quartz and felspar predominate, mica being also quite abundant, and sometimes in plates 2 ft. across. The tourmalines and associated minerals, like lepidolite, beryl, cookeite, etc., occur usually in pockets, all of which are lined with crystallized quartz and felspar, and sometimes beryl. *All* the minerals occur in these pockets. The deposit is well defined between walls of country rock—possibly gneiss, but I am not positive.'

In the following description of the species, the position of the crystals and the lettering of the faces are throughout those used in Dana's 'System of Mineralogy' (1892); as are also the axes, except in the case of tourmaline, where the faces are referred to the rhombohedral axes of Miller. In the case of apatite and beryl, the letters and indices used by Miller (in his edition of Phillips's 'Mineralogy') are added.

THE MICAS.

Intergrowth of Muscovite and Lepidolite.

Perhaps the most interesting minerals of the occurrence are the micas. Stout hexagonal or rhombic prisms terminated at right angles by the basal plane are found associated with smoky quartz, albite, microcline, cookeite, and sometimes tourmaline. They have ordinarily a diameter of 1·5 to 3 or 4 cm., but to judge from one tabular (cleavage) specimen, they appear to attain a diameter of 8 cm. They are usually terminated by cleavages, but some specimens attain a length of 4 cm. When broken across, they are found to consist either of transparent lilac lepidolite throughout, or (more usually) of an outer zone of this mineral surrounding an inner nucleus of yellowish- or greenish-white muscovite, the cleavage being parallel in both border and centre.

Pink Fibrous Muscovite.

The outer surface of the prisms has a fibrous appearance due to a thin layer of longitudinal fibres of a pink mineral, and at the ends the lepidolite is covered (in unbroken specimens) by a layer of the

same material, often 1 cm. or more in thickness, the fibres being always parallel to the axis of the prism. The fibrous mineral has a perfect cleavage perpendicular to its fibres, and thin plates can be split off from it parallel to the cleavage of the lepidolite nucleus. Such plates form beautiful objects under the microscope, when they are seen to be built up of minute rhombic units, with angles of 60° and 120°, fitted together in three positions, forming tesselated areas which extinguish in three positions, 120° apart—each rhomb extinguishing parallel to its diagonals (fig. 1, plate IV). In convergent light the rhombs show a nearly normally-emergent negative bisectrix of rather wide angle, the plane of the optic axes lying along the longer diagonal.

These characters indicated a mineral belonging to the group of micas, and an analysis became necessary in order to determine the species.

The material analysed was of a uniform light rose-pink, and quite clean and free from any brown crust. Its specific gravity (before crushing) was 2·791.

A small amount of water is given off on heating the dried powder in the closed tube, and a qualitative examination showed the presence of SiO_2, Al_2O_3, Fe_2O_3 (or FeO), MnO, K_2O, Na_2O, Li_2O, F, P_2O_5. The MnO is sufficient to give the fused carbonates a pale bluish-green tinge, and is probably the cause of the pink colour of the mineral, but it does not appear to be present in weighable amount.

The finely powdered mineral was found to show practically no loss of weight after being exposed for forty-eight hours over calcium chloride, and a very trifling loss after being heated for two hours to about 96° in a water-oven. For the quantitative determinations, therefore, the material was dried in this manner.

The water was estimated by Penfield's direct method[1], the mineral, mixed with previously well dried litharge to retain fluorine, being heated by a Bunsen burner in a closed hard-glass tube with a bulb on its neck kept cool by wet filter-paper. The neck containing the water was cut off and weighed, the water then tested and found neutral, and the neck dried and again weighed. Further heating of the residual material in the blowpipe produced no more water. In two experiments, 0·0975 and 0·0759 grams of the dried mineral gave 0·0043 and 0·0033 grams of water, corresponding to 4·41 and 4·35 per cent. respectively of water [mean 4·38 per cent.].

The fluorine was determined according to the method of Berzelius; two experiments with 0·1186 and 0·2531 grams of the dried mineral

[1] Amer. Journ. Sci., 1894, ser. 3, vol. xlviii, p. 31.

yielding (after removal of one-tenth of the solution to test for P_2O_5) 0·0008 and 0·0018 grams of calcium fluoride, corresponding to a total percentage of fluorine of 0·37 and 0·385 [mean 0·377].

The determinations of the silica by the Berzelian method were not concordant, and this constituent was therefore estimated in the usual way by evaporation of the carbonate-fusion with acid, the amount of fluorine being so small that any loss of silica which it might cause (the maximum possible being just over three-quarters of its weight) must be insignificant. Seven experiments yielded the numbers given below. The acid solution was in each case evaporated twice on the water-bath and extracted through separate filters, and in nos. 3, 4, 5, 6 the residue after the second evaporation was heated to 110° in an air-bath, till it no longer gave off acid fumes. In the case of nos. 3, 4, 7, nitric acid was used instead of hydrochloric acid.

The weighed silica was exposed in the open platinum crucible to the fumes of hydrofluoric acid (produced from a mixture of NH_4HF and strong sulphuric acid) for 12–15 hours in a closed leaden box[1] over a small flame placed some distance below, and the silica determined by the loss of weight.

	1	2	3	4	5	6	7	
Weight of mineral .	0·3827	0·2423	0·3023	0·3208	0·3069	0·3045	0·3004	
Weight of SiO_2 . .	0·1792	0·1112	0·1399	0·1475	0·1419	0·1409	0·1396	
Percentage of SiO_2 .	46·83	45·89	46·28	45·98	46·24	46·27	46·47	mean 46·28

The filtrates from the silica in nos. 1, 2, 6 were precipitated hot with ammonia, the precipitate washed, dissolved in nitric acid, and reprecipitated; the precipitate of Al_2O_3, Fe_2O_3, P_2O_5, after weighing, was tested for manganese by fusion with carbonates, but gave hardly any perceptible green colouration. The weights of the precipitates were 0·1456, 0·0917, 0·1153 grams, corresponding to 38·05, 37·85, 37·87 per cent. of $(Al_2O_3+Fe_2O_3+P_2O_5)$ respectively. [Mean 37·92 per cent.]

The filtrates from the silica in no. 5 and in another experiment with 0·3077 gram of the dried mineral, were precipitated with ammonia, the precipitate washed and redissolved in dilute sulphuric acid, the iron

[1] Such a box may conveniently be made of a piece of 4 in. lead pipe, about 4 in. long, with the ends filed true and closed by flat plates of sheet lead. The crucible is covered with a loose roof of platinum foil to protect the silica from any particles falling from the lid of the box.

reduced with zinc and titrated with permanganate. The results showed 1·07 and 0·87 per cent. of ferric oxide, respectively. Ferrous iron was not separately determined. [Mean Fe_2O_3=0·97 per cent.]

In the filtrate from no. 7, the phosphoric acid was separated with ammonium molybdate and estimated as $Mg_2P_2O_7$. The result showed the presence of 0·09 per cent. P_2O_5.

Taking the means of the determinations and calculating the alumina by difference gives 36·86 per cent. Al_2O_3.

For the estimation of the alkalies the mineral was decomposed by the Lawrence Smith method and the separation of the lithium effected by means of amyl alcohol as recommended by Gooch[1]. The lithium was weighed as lithium sulphate. The potassium was separated from the sodium in the residue as K_2PtCl_6, the latter ignited, and the resulting platinum washed and weighed. The weight of sodium was obtained by difference.

The results of three experiments with 0·3096, 0·3049, and 0·3986 grams of the dried mineral, after correction for the solubility of the various alkaline salts in the amyl alcohol, gave the following percentages:—

	1	2	3	mean
Li_2O	0·31	0·25	0·21	0·26
K_2O	10·90	10·53	10·46	10·63
Na_2O	1·37	1·52	1·33	1·41

The composition of the mineral may then be taken as:—

	I. Haddam Neck.	Goshen. II. Rbg.	Goshen. III. Mallet.
SiO_2	46·28	47·02	
Al_2O_3	36·86	36·83	
Fe_2O_3	0·97 (incl. FeO)	0·51	
MnO	trace	1·05	
K_2O	10·63	9·80	9·08
Na_2O	1·41	0·30	0·99
Li_2O	0·26		0·64
P_2O_5	0·09	—	
F	0·377	0·52	1·89
H_2O	4·38	3·90	
	101·257	99·93	
less O	0·158		
	101·099		

[1] Proc. Amer. Acad. Arts and Sci., 1886, new ser., vol. xiv, p. 177; Bull. U. S. Geol. Survey, 1887, no. 42, p. 73; Chem. News, 1887, vol. lv, p. 18, et seq.

The mineral is therefore a variety of muscovite, and may be compared with the pink variety of muscovite from Goshen (Massachusetts), the analysis of which, by Rammelsberg[1], is quoted in column II. A determination of the alkalies of the same by Mallet[2] is also given in column III.

A small fragment of a fibre detached from the side of a specimen admitted of measurement on the goniometer, and proved to be a very steep pyramid (fig. 2, plate IV[3]), the vertical faces not lying in a zone. The angles are:—

	Measured.	Calculated.
SS	$= 59° 52'$	$59° 58'$
$\pi\pi$	$= 59\ 43$	$59\ 52$
cS	$= 88\ 21\frac{1}{2},\ 88° 21'$	$88\ 36\frac{1}{2}$
$c\pi$	$= 86\ 38,\ 86° 33'$	$86\ 28$

The plane of symmetry is thus parallel to the shorter diagonal of the rhomb. The measured angles lead to the indices $S\ \{\bar{5}51\}$ and $\pi\ \{\bar{5}52\}$. Both forms are new for muscovite, but $S\ \{\bar{5}51\}$ is given by Dana for biotite. The corresponding calculated angles given above are based on Tschermak's axes $a : b : c = 0{\cdot}57735\ \ 1 : 3{\cdot}3128$; $\beta = 89° 54'$, as adopted by Dana for muscovite.

The axial angle measured in air is:—

$$2E = 75\tfrac{1}{2}°\ (\text{Na light}).$$

Dispersion, $\rho > v$ (slight).

The acute bisectrix is perhaps not quite normal to the plate, and in some instances seems to deviate a few degrees *in* the plane of the optic axes (i. e. across the plane of symmetry), but owing to the small size of the rhombs and the difficulty of isolating them, the position of the plate-normal has not been ascertained with certainty.

Some of the cleavage flakes show a bright line, which does not extinguish, along the boundary between the areas with different orientation, due to overlapping of the contiguous elements, and corresponding with the obliquity of the prism faces with respect to the cleavage.

The tesselated structure gives the mineral an opaque appearance to the naked eye, though the separate elements are transparent. The size of the small rhombs is on the whole very uniform, being about 0·18 mm. for the longer diagonal, but a few isolated fibres reach 0·65 mm.

I was for a long while unable to find any specimens from other

[1] Min.-Chem., 1875, p. 514.

[2] Amer. Journ. Sci., 1857, ser. 2, vol. xxiii, p. 180.

[3] The convergence of the faces is somewhat exaggerated in the figure.

localities at all resembling the present mineral, but among the lepidolites in the Vienna Museum I came upon a single large tabular crystal of muscovite bordered by a zone of lilac lepidolite, outside which was a small quantity of rhombic, tesselated material. The specimen is from Auburn, Maine, and proves on examination to be very similar to those of the Haddam Neck occurrence. The rhombs are fitted together in twin-position, extinguishing 120° apart. The axial plane is parallel to the longer diagonal. The axial angle is rather wide ($2E = 75° 20'$), and the figure shows distinct axial dispersion, $\rho > v$. The lilac lepidolite has its axial plane parallel to one of the rays of the percussion figure, and is therefore brachydiagonal. It is much twinned. The muscovite centre is macrodiagonal, with rather wide axial angle, and very distinct dispersion, $\rho > v$. The whole specimen very closely resembles the large tabular crystal from Haddam Neck mentioned above.

Lepidolite.

The solid prisms of lepidolite and the borders surrounding muscovite form extremely fine examples of this mineral. The material is of a beautiful lilac colour and perfectly transparent. To the eye it appears quite uniform and homogeneous, but application of the percussion test combined with the microscope, shows that the crystals fall really into two groups, in one of which the axial plane is brachydiagonal, while in the other it is macrodiagonal. It may be mentioned that the lepidolite yields a percussion figure much less readily than the muscovite, being more flexible and less elastic than it.

Lepidolite is usually stated to belong to the macrodiagonal group of micas, but brachydiagonal lepidolite has been described by Scharizer[1] from Schüttenhofen in Bohemia, where the zonal growth of the lepidolite and muscovite and the tourmalines appear to show a general resemblance to those of the present occurrence. Cleavage plates of the Haddam Neck lepidolite do not as a rule extinguish at all unless very thin, owing to the superposition of layers of material in twin-position. Thin plates show an irregular patchwork of areas extinguishing 120° apart. The axial angle is variable on account of the twinning, but appears to be generally smaller than that of the muscovite.

Both the brachy- and macrodiagonal varieties show a slight dispersion of the optic axes, in the sense $\rho > v$. The brachydiagonal flakes show a deviation of the bisectrix from the plate-normal in the plane of the optic axes. The macrodiagonal flakes also show a deviation of the

[1] Zeits. Kryst. Min., 1886, vol. xii, p. 1.

bisectrix of from $5\frac{1}{4}°$–$7\frac{1}{2}°$ from the centre of the microscope field, which is again in the plane of the optic axes, and therefore in this case in the plane perpendicular to (010). A deviation of this sort would contradict the assumption of monoclinic symmetry for the crystals, and it was therefore of importance to determine if the effect was real or due to instrumental errors (such as want of perpendicularity between the stage and the axis of the microscope), or to the somewhat uneven cleavage flake not lying flat upon the stage.

A small and exceptionally plane flake having been chosen, it was cemented on to a thin cover-glass in such a position that when mounted on the goniometer the best image of the signal reflected from the mica was not more than a few minutes distant from that reflected from the glass. The parts of the flake yielding other images were covered with a mask of paper. The mounted flake was then placed on a disc of glass laid flat on the stage of the microscope (Dick pattern), and capable of rotating in its own plane within a cardboard ring. The positions of the optic axes O_1O_2 in the field were read off on an eyepiece-micrometer, first in one position (A), and then after rotating the plate on the stage through 180° (B). The mean of O_{1_A} and O_{1_B} (or O_{2_A} and O_{2_B}) gives the reading for the plate-normal, while those of O_{1_A} and O_{2_A} and of O_{1_B} and O_{2_B} give readings for the bisectrix in the two positions.

A flake, which was subsequently proved by percussion to be macrodiagonal, showed a deviation of the bisectrix from the plate-normal of $6\frac{1}{2}°$ in the plane of the optic axes, the inclination of the mica to the cover-glass being only 16′. The true deviation of the bisectrix from the normal to the flake in the plane of the optic axes cannot therefore be less than $6\frac{1}{4}°$.

Hence it must be concluded that, unless a ray of the percussion star is perpendicular to (010) [1], this mica belongs to the anorthic system.

With the nicols in the extinction position, the lateral shift of the axial brush produced by a rotation of the plate through 180° falls within the errors of observation. The axial plane is thus sensibly normal to the plane of cleavage.

Another flake, examined as above, which turned out to be brachydiagonal, showed a deviation of $4\frac{3}{4}°$ in the plane of the optic axes, the

[1] There seems no reason to doubt that the star belongs to a percussion- and not to a pressure-figure, as its form agrees exactly with the type figured by Max Bauer (Zeits. Deutsch. geol. Gesells., 1874, vol. xxvi, pl. II, fig. 2, and copied in Hintze's Mineralogy, vol. ii, p. 518, fig. 236).

mica being nowhere inclined more than 7′ to the plate on which it was mounted.

Greenish-white Central Muscovite.

The central core of many of the mica crystals consists of greenish- or yellowish-white muscovite, and a similar material also occurs in irregular flakes dispersed in parallel positions through massive quartz.

The centre of the large tabular crystal mentioned above (p. 98) has an axial angle in air[1]:—

$$2E = 75° 38'.$$

That of a smaller rhombic-shaped prism has:—

$$2E = 74° 35'.$$

The material is a perfectly normal muscovite—the axial plane is macrodiagonal, and there is a well-marked axial dispersion, $\rho > v$.

Zonal Growth and Twinning of the Micas.

(1) *Lepidolite on Muscovite.*—The line of junction between the central muscovite and the lepidolite border is occasionally irregular, but more usually straight and sharp. The outline is generally either rhombic or hexagonal, corresponding to faces in the zone $[c, (110)]$ and the clinopinakoid $\{010\}$ of the muscovite. The obtuse angles of the rhomb are often truncated by small faces of a $\{100\}$, and the angles between $\{010\}$ and $\{110\}$ are frequently replaced by short edges apparently representing several different forms. The indices of these can scarcely be determined owing to the shortness of the edges and the rounding of the angles, but Q $\{130\}$ is probably present, and two faces at angles, respectively, of 23° and 24° from $\{110\}$, may belong to a form $\{370\}$, for which the calculated angle (taking $(110) : (1\bar{1}0) = 60°$) is 23° 25′. Seven measurements (varying from 59° to $60\frac{1}{2}°$) of the plane angle of the rhomb on the microscope-stage yielded $59\frac{1}{2}°$ as the mean value of that angle.

The relation of the lepidolite border to the central muscovite is somewhat difficult to determine, owing to the twinned structure of the former; the untwinned areas being so small as to admit only exceptionally of the production of a recognizable percussion figure.

Immediately outside the junction is generally (but not always; see fig. 4, pl. IV) a narrow band of lepidolite (L_m) which extinguishes in the same position as the muscovite, the axial planes being also parallel (fig. 3, pl. IV). The percussion star, which I have succeeded in obtaining on

[1] For the muscovite-centre of the zoned mica from Schüttenhofen, the axial angle (as given by Scharizer) is $2E = 70°$–$74°$.

two specimens, shows this zone to consist of the macrodiagonal variety grown in parallel position on the muscovite.

Outside this inner zone of lepidolite, and occasionally also in direct contact with the muscovite, are irregular patches (L_b) having their axial planes parallel to one side or the other of the rhombic outline of the muscovite, i.e. at 30° in one direction or the other from that of the muscovite. Those of these patches which have yielded me a percussion figure are found to be brachydiagonal, and all are probably to be explained as brachydiagonal mica in twin-position according to the ordinary 'mica-law' (twin plane {110}).

The extinction of the lepidolite and also of the muscovite in the neighbourhood of the junction, is somewhat wavy, and cannot therefore be determined with sufficient accuracy to afford an answer to the questions, whether the lepidolite in contact with muscovite is twinned on that mineral or on the zone of lepidolite parallel to it (in cases like fig. 4), and whether the latter is absolutely parallel with the muscovite or grown upon it with the prism faces in common. The wavy extinction may probably itself be an indication of the strain set up by want of complete coincidence between the molecular structures of the two minerals.

In the larger crystals, the lepidolite border is composed of intimately twinned material and scarcely extinguishes anywhere. Here and there, however, in thin flakes, small patches may be found, on which the extinction directions may be determined. Those adjoining the junction have their axial plane parallel to that of the muscovite and are probably macrodiagonal; others, in the body of the lepidolite, have the axial plane inclined at 30° to that of the muscovite, and are shown by the percussion figure to consist of the brachydiagonal variety in twin-position.

The outer boundary of the lepidolite is consistently parallel to its junction with the muscovite, though in the larger crystals it is somewhat rough and irregular. This parallelism is maintained irrespective of the face which is in contact with the muscovite; thus, along the prism edge of a muscovite rhomb, in the case of lepidolite in either parallel position or twin-position about that prism face, the outer edge corresponds to {110}, while both the line of contact and the outer edge of an area of lepidolite twinned about the other prism face, represent {010} (see fig. 4).

(2) *Pink fibrous Muscovite on Lepidolite.*—The junction of the lepidolite with the border of pink fibrous muscovite is usually quite sharp and straight. The small rhombs are either in parallel position on the lepidolite or twinned upon it according to the ordinary mica-law. The general structure of the border is shown in fig. 5, pl. IV, which represents

a flake from a hexagonal lepidolite prism without any central core of muscovite. The flake consists of three macrodiagonal lepidolite crystals, irregularly twinned together, and the sides of the hexagon are formed principally by {010}; {110} is also present on one individual, and the corners of the hexagon are truncated by short edges corresponding to {130}.

The arrangement of the rhombs round brachydiagonal lepidolite is quite similar, the crystals being sometimes attached in parallel and sometimes in twin-position, and the axial planes being at 90° and 30° respectively to that of the lepidolite.

The chief points of interest shown by this occurrence of micas may be thus summarized:—

A new variety of muscovite, which appears to be scarcely met with elsewhere, is here very abundant. It consists of masses of pink fibres of rhombic section attached together in parallel or twin-position, so that the whole mass can be cleaved across like a single crystal. The fibres generally occur surrounding, or at the ends of, lepidolite crystals, and at first sight resemble an alteration-product of the latter.

The lilac-coloured lepidolite occurs either in solid prismatic crystals or as a border surrounding greenish-white muscovite, and comprises two varieties, differing only in the position of the optic axial plane, which is parallel respectively to the brachydiagonal or macrodiagonal axis. In the latter case, a deviation of the acute bisectrix from the plane (010) indicates that this mica is to be referred to the anorthic system. The lepidolite is usually much twinned on the ordinary 'mica-law.' The muscovite is generally surrounded by a narrow zone of macrodiagonal lepidolite (fig. 3, pl. IV) in parallel position, while outside this are patches of brachydiagonal lepidolite twinned on each other and on the zone of macrodiagonal material. Among them are sometimes found patches of the macrodiagonal variety. I have found no instance of brachydiagonal lepidolite attached to the muscovite in parallel position, nor of macrodiagonal in twin-position, but brachydiagonal lepidolite is sometimes in direct contact with the muscovite in twin-position (fig. 4, pl. IV).

The lepidolite is often surrounded by a layer of the rhombic fibres of pink muscovite in either parallel or twin-position, the arrangement being similar round both brachy- and macrodiagonal varieties.

The intimate association of the two varieties of lepidolite does not seem to have been observed before, and being thus unsuspected it caused

at first some little difficulty in explaining the relations of the border to the muscovite.

No case was observed in which any other than the ordinary twin-law need be invoked in order to explain the relative positions of the various areas.

Colourless Muscovite.

Besides the greenish-white muscovite described above in association with the lepidolite, there also occur large sheets (sometimes two feet across, as Mr. Schernikow reports) of ordinary clear colourless muscovite, such as is used commercially, which is brownish in thick sheets. This mica contains thin included films of a dark material appearing bronze-coloured by reflected light, and opaque or of a very dark grey by transmitted light under the microscope. The inclusions are hexagonal in outline, the sides of the hexagons being perpendicular to the percussion-rays, and are traversed by cracks perpendicular to the sides of the hexagons; they reach a breadth of 2–3 mm., but are mostly smaller. I have not been able to isolate, or determine the nature of these inclusions owing to their extreme thinness. They do not appear to affect the magnetic needle.

Flattened tabular and elongated crystals of black, brown, and green tourmaline are also enclosed in this mica. The axial plane of the mica is macrodiagonal and the axial angle in air, $2E = 71° 0'$.

Tourmaline.

The tourmaline occurs in the form of beautiful, transparent, striated prisms, of curved triangular outline or flattened, and varying much in colour—the most usual colours being shades of light and dark green and pink[1]. A few crystals are almost perfectly colourless. Crystals frequently exhibit transverse bands of different colours, which are usually separated from each other by perfectly sharp planes perpendicular to the prism, or the junctions may be slightly hazy though still parallel to (111). In one case, the junction between a pale green and a pink band shows the form of the trigonal pyramid $\{11\bar{1}\}$ (fig. 6), and sometimes the pyramidal termination $\{11\bar{1}\}$ shows a thin parallel layer covering the faces of an earlier termination of the same form but of a different colour. The frequency of the occurrence of the basal plane alone among these colour divisions is somewhat remarkable, as this form is usually but poorly developed in the present terminations of the crystals. Occasionally the later growth has extended from the terminal

[1] Mr. Spencer informs me (January, 1902) that the pink specimens in the British Museum have faded very markedly during four years' exposure in a glass case.

band backwards along the prism, forming an outer zone of differently coloured material.

The crystals bear no resemblance to the well-known tourmalines 'from Haddam,' which are black.

The crystals are frequently doubly-terminated: they vary in habit from short and stout (30 mm. long and 20 mm. diam.) to long and slender (80 × 4 mm.)[1], and small, almost acicular crystals are found scattered over the surface of larger ones or embedded in other minerals.

The following forms are present:—

Antilogous pole . . o {11$\bar{1}$}
Analogous pole . . e {0$\bar{1}\bar{1}$}, r {$\bar{1}$00}, c {$\bar{1}\bar{1}\bar{1}$}.

There does not appear to be any connexion between the colours of the ends and the polarity of the crystals.

G. Rose stated[2] that, as a general rule, that end at which the faces of the principal rhombohedron [trigonal pyramid] (RR=46° 54′) lie over the edges of the trigonal prism, is the antilogous pole, and vice versa, but found that crystals from Penig in Saxony formed an exception to this rule, having the faces of R over the *faces* of the trigonal prism at the antilogous pole.

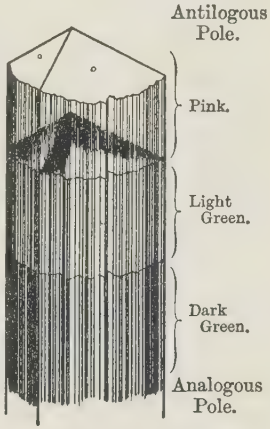

Fig. 6.—Banded crystal of tourmaline showing an internal 'ghost.' (Length 30 mm., diam. 5 mm.)

This rule may be taken as equivalent to the statement that (the antilogous pole being placed uppermost) +R {100} {$\bar{1}$00} and the prism {$\bar{2}$11} are the more commonly occurring forms as compared with the corresponding inverse forms − R {22$\bar{1}$} {$\bar{2}\bar{2}$1} and {2$\bar{1}\bar{1}$}. An exception to the rule may be due to the presence of either (*a*) the rarer inverse pyramids −R {22$\bar{1}$} {$\bar{2}\bar{2}$1} (combined with {$\bar{2}$11}), or (*b*) the rarer complementary trigonal prism {2$\bar{1}\bar{1}$} (combined with +R). The occasional occurrence of the latter prism on tourmaline is proved by the simultaneous existence, on crystals from Bovey Tracey, Sonnenberg in the Harz, and Gouverneur, of both trigonal prisms, of which {2$\bar{1}\bar{1}$}

[1] Some specimens in the British Museum attain a length of 5 inches, and Kunz mentions and figures (18th Ann. Rep. U. S. Geol. Survey, 1896–7 (1897), part v, pp. 1183, 1204; 20th Rep., 1898–9 (1899), part vi (2), plate I, fig. E) a perfect crystal 10 in. long × 1 in. diam. in Mr. Bement's Collection.

[2] Ann. Phys. Chem. (Poggendorff), 1836, vol. xxxix, p. 285; 1843, vol. lix, p. 357.

in the first two cases sometimes, and in the latter case habitually predominates[1].

The exception in the case of the Penig crystals is perhaps to be explained (as Rose at first suggested) on the first assumption, as the R-faces are very rough and the faces of the flatter rhombohedron truncating the edges of R, very smooth and shining, while normally the reverse of this is found to hold. (According to von Worobieff, however, this explanation is not likely to be correct.)

An examination of a number of the Haddam Neck crystals by Kundt's method showed them to conform to the above rule; they also confirm Rose's further statement that the basal plane only occurs on the analogous pole.

The faces of r $\{\bar{1}00\}$ are always bright, while those of e $\{0\bar{1}\bar{1}\}$ are usually so, but occasionally dull and drusy; o $\{11\bar{1}\}$ is bright but generally somewhat pitted.

The mean pyramid-angle of $\{11\bar{1}\}$, as determined from four measurements on pink crystals, is 76° 37′ (76° 18′—76° 45′), giving 114° 4′ for the axial angle. Two measurements on green crystals gave 76° 45′ as the pyramid-angle, corresponding to 114° 0′ as the angle between the axes.

The lighter coloured crystals are usually but slightly pleochroic, while in some of the darker green varieties the ordinary ray is almost completely absorbed. The pleochroism corresponding to the various colours is indicated in the following table:—

Colour.	Vibrations	
	∥ axis (extraordinary ray).	⊥ axis (ordinary ray).
Rose-pink	Dark pink	Ruby.
„ „	Pink	Pink.
„ „	Very pale lilac	Brown-pink.
Nearly colourless	Pale blue	Pale brown-pink.
Bluish green	Pale blue	Light olive.
„ „ (darker)	Leek-green	[Nearly dark.]
Greyish green	Greyish green	Olive.
Light green	Pale greenish blue	Olive-green.
Dark green	Grass-green	[Dark.]
Violet	Pale mauve	[Nearly dark.]

[1] V. von Worobieff has recently found in the course of his exhaustive study of tourmaline (Zeits. Kryst. Min., 1900, vol. xxxiii, p. 419) a large number of exceptions to Rose's rule, so that the latter can no longer be said to be of general application. The number of forms on the crystals from Haddam Neck is too small to permit the determination of the polarity by the rules proposed by v. Worobieff, but the occurrence of o $\{11\bar{1}\}$ at the antilogous pole is in accordance with his observations.

Some of the 'uniform, rather pale green crystals' have been analysed by Penfield and Foote[1], who give the following composition :—

$SiO_2 = 36{\cdot}96$, $TiO_2 = 0{\cdot}03$, $B_2O_3 = 11{\cdot}00$, $Al_2O_3 = 39{\cdot}56$,
$FeO = 2{\cdot}14$, $MnO = 2{\cdot}00$, $MgO = 0{\cdot}15$, $CaO = 1{\cdot}28$,
$Na_2O = 2{\cdot}10$, $Li_2O = 1{\cdot}64$, $H_2O = 3{\cdot}10$, $F = 1{\cdot}13$.

Total =	101·09
less O =	0·48
	100·61

Flattened tabular crystals of black tourmaline are found (as are also thin prisms of the green variety) between the laminae of large sheets of the ordinary white muscovite; but no black crystals appear to occur in association with the other minerals, though a few green crystals are so dark as to appear almost black.

Kunz states[2] that a number of crystals have been found showing marked internal striations, arranged in such a way as to show in gems cut across the crystal a line of light, similar to the 'cat's-eye' variety of chrysoberyl from Ceylon.

Apatite.

Two varieties of this mineral are found, viz. thick hexagonal tables or short prisms (up to 2 cm. diam.) of a pale greyish green, and rose-coloured crystals having the form of short, stout prisms terminated by the basal plane. The prism- and basal-edges of both varieties are modified by narrow faces.

The greenish crystals occur embedded in albite and quartz: the pink crystals in the Oxford Collection do not show any matrix.

The following are the forms found on the pink crystals :—

Bowman.	Dana.		Miller.	
	m	{10$\bar{1}$0} . . .	a {10$\bar{1}$}	
	a	{2$\bar{1}\bar{1}$0} . . .	b {2$\bar{1}\bar{1}$}	
	h	{32$\bar{1}$0} [or h' {3$\bar{1}\bar{2}$0}].	h {32$\bar{1}$}	narrow faces replacing
*W	–	{75$\bar{2}$0} [or W' {72$\bar{5}$0}]	– {75$\bar{2}$}	the edges of m and a.
	c	{0001} . . .	o {111}	
	r	{10$\bar{1}$2} . . .	i {321}	
	x	{10$\bar{1}$1} . . .	x {210}	
	y	{20$\bar{2}$1} . . .	z {31$\bar{1}$}	
	s	{2$\bar{1}\bar{1}$1} . . .	r {100, 22$\bar{1}$}	

[1] Amer. Journ. Sci., 1899, ser. 4, vol. vii, p. 107; and Zeits. Kryst. Min., 1899, vol. xxxi, p. 333.

[2] 19th Ann. Rep. U. S. Geol. Survey, 1897–8 (1898), part vi, p. 505.

The green crystals are richer in forms, and exhibit the distribution of faces shown in the projection, fig. 7:—

Bowman.	Dana.		Miller.	
	m	$\{10\bar{1}0\}$	a	$\{10\bar{1}\}$
	a	$\{2\bar{1}\bar{1}0\}$	b	$\{2\bar{1}\bar{1}\}$
	h	$\{3\bar{2}\bar{1}0\}$	h	$\{3\bar{2}\bar{1}\}$
h'	h_1	$\{3\bar{1}\bar{2}0\}$	h	$\{3\bar{1}\bar{2}\}$
k'	–	$\{5\bar{1}\bar{4}0\}$	k	$\{5\bar{1}\bar{4}\}$ narrow faces replacing the
$*l$	–	$\{7\bar{4}30\}$	–	$\{7\bar{4}\bar{3}\}$ edges of m and a.
$*W$	–	$\{7\bar{5}\bar{2}0\}$	–	$\{7\bar{5}\bar{2}\}$
$*W'$	–	$\{7\bar{2}\bar{5}0\}$	–	$\{7\bar{2}\bar{5}\}$
	c	$\{0001\}$	o	$\{111\}$
	r	$\{10\bar{1}2\}$	i	$\{321\}$
	x	$\{10\bar{1}1\}$	x	$\{210\}$
	y	$\{20\bar{2}1\}$	z	$\{13\bar{1}\}$
	s	$\{2\bar{1}\bar{1}1\}$	r	$\{100, 22\bar{1}\}$
	v	$\{2\bar{1}\bar{1}2\}$	e	$\{411, 110\}$ small uneven faces, each
	μ	$\{3\bar{2}\bar{1}1\}$	u	$\{4\bar{1}0, 23\bar{2}\}$ observed once only.

Of these, l, W, W' are new forms.

The form l occurs five times, on four crystals, as a narrow face on the edge a/m. One of these crystals also bears μ on the same side of a as l, and hence, assuming μ to be $\{21\bar{3}1\}$ (this being commoner than μ_1 $\{12\bar{3}1\}$), l must be $\{43\bar{7}0\}$. No evidence was found of the complementary form $\{34\bar{7}0\}$.

The form k' occurs once as a narrow face, in combination with l but on the opposite side of a, the faces present being $[mhamlak'm]$; its symbol must therefore be $\{14\bar{5}0\}$. Haidinger[1] mentions a form 'f' found on a crystal from St. Gothard, which from his figure and description must correspond to this form. It was, however, afterwards omitted by him from the (otherwise similar) figure (fig. 148, pl. xxvii.) in his edition of Mohs' 'Mineralogy' (Edinburgh, 8 5), though it remains ($f\,(P+\infty)$[3]) in the list of forms (vol. ii, p. 74). Apparently on this ground its existence was doubted by Schrauf[2]. Des Cloizeaux figures[3] a corresponding form 'h^4,' on the same side of a as μ, on crystals 'from Cornwall,' and

[1] Edinb. Phil. Journal, 1824, vol. x, p. 148, and pl. v, fig. 16; Isis, 1824, p. 852.

[2] Ber. Akad. Wien, 1870, vol. lxii (2), p. 754. Dana (System, 1892, p. 768, Ref. [4]) mentions k $\{41\bar{5}0\}$ as having been questioned by Schrauf. The latter was however only referring to Haidinger's form ($k'\{14\bar{5}0\}$), though his symbols cover both k and k'.

[3] Manuel de Min., vol. ii, p. 434, and pl. lxxiii, figs. 442, 443.

on both sides of a on crystals 'from Jumilla.' I have, however, been unable to discover the source of these figures. The complementary form k {4150} has been found by E. S. Dana on a crystal from Paris, Maine [1]. It does not, however, appear to occur on the present crystals.

The form h {2130} is holohedrally developed, as noted by Kenngott [2] and confirmed by Klein [3], on crystals from Poncione della Fibia in the St. Gothard. So also is the new form W {5270}. The evidence for this

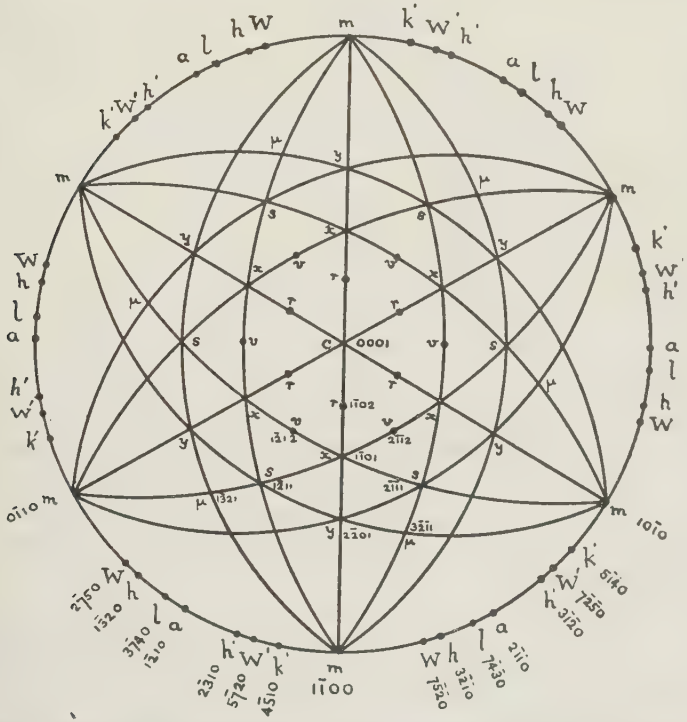

FIG. 7.—Stereographic projection of apatite showing all the forms observed at Haddam Neck.

is derived from two of the greenish crystals showing the following faces in the prism zone:—

(1) [*mlamhamhamlah'mah'm*]. (This is the crystal showing μ, mentioned above.)

[1] Amer. Journ. Sci., 1884, ser. 3, vol. xxvii, p. 480.
[2] Min. d. Schweiz, 1866, p. 353.
[3] Neues Jahrb. Min., 1871, p. 485.

(2) [*maW'mWhah'mWlam*].

W (or *W'*) also occurs on one of the pinkish crystals, combined only with *m* and *a*. Here the two forms cannot be distinguished, as also happens in the case of *h* (or *h'*) occurring with only *m* and *a* upon another pink crystal.

The evidence for the new and doubtful forms is based upon the following measured angles:—

		Edges.	Limits.	Observed mean.	Calculated. $c' = .734603$ (Koksharov).
al	$= 1\bar{2}10 : 3740$	5	4° 8′ – 5° 50′	4° 44′	4° 43′
mh	$= 1\bar{1}00 : 32\bar{1}0$	5	18 22 – 19 9	19 5	19 6
mh'	$= 1\bar{1}00 : 2\bar{3}10$	3	18 55 – 19 47		
m (*h* or *h'*)	$= 1\bar{1}00 : (32\bar{1}0 \text{ or } 2\bar{3}10)$	4	18 45 – 19 27		
mk'	$= 1\bar{1}00 : 4\bar{5}10$	1	—	11 13	10 54
mW	$= 1\bar{1}00 : 75\bar{2}0$	2	14 34 – 16 45	15 38½	16 6
mW'	$= 1\bar{1}00 : 5\bar{7}20$	1	15° 28′		
m (*W* or *W'*)	$= 1\bar{1}00 : (75\bar{2}0 \text{ or } 5\bar{7}20)$	1	15 49		

The basal plane is bright and gives very perfect reflections, but it appears uneven to the naked eye, owing to its surface being broken by shallow hexagonal pits (2 mm. diam.), which have their edges parallel to the edges *c*/*m*, and are bounded by somewhat curved vicinal faces, *P*, approximating to $\{2\cdot\bar{2}\cdot 0\cdot 19\}$. These faces also occur occasionally upon the edges of the basal plane, as do faces of a form *Q*, near to $\{2\bar{2}07\}$.

The angles are:—

	Edges.	Limits.	Observed mean.	Calculated.
$cP = 0001 : 2\cdot\bar{2}\cdot 0\cdot 19$	5	4° 46′ – 5° 27′	5° 4′	5° 6½′
$cQ = 0001 : 2\bar{2}07$	2	13 9 – 14 8	13 38½	13 37

The faces of *m* are bright and yield excellent reflections; those of *a* are slightly striated parallel to the edge *a*/*m*.

Microcline.

This occurs in stout, greenish-white, opaque crystals (up to 5 cm. high and 4 cm. thick) of the usual habit, which are often very drusy and cavernous, especially on the faces *c* $\{001\}$, *x* $\{10\bar{1}\}$. Minute brilliant

crystals of albite and crusts of cookeite are sometimes found on the surface.

The following forms are present:—

c {001}, b {010}, m {110}, M {1$\bar{1}$0}, f {130}, ζ {1$\bar{5}$0}, x {10$\bar{1}$}, y {20$\bar{1}$}, p {$\bar{1}$11}, o {$\bar{1}\bar{1}$1}.

Cleavage flakes parallel to c {001} sometimes show the microcline structure; some are free from twinning and have an extinction angle of about 14°. The extinction angle through a b-cleavage is about +7°; these flakes show an obliquely emergent positive bisectrix.

Some crystals exhibit a cross-hatching, visible to the naked eye, upon the faces c and x.

The specimen carrying colourless beryl, and also a beryl specimen in the British Museum, show a pegmatitic intergrowth of quartz with white microcline.

Albite.

The crystals of this mineral are large and well formed: they are either flattened parallel to b {010} or elongated parallel to x {$\bar{1}$01}, and aggregated in parallel or twin-position to form a group which presents the aspect of a large crystal elongated in the direction of the axis b.

Stout, single crystals are occasionally found (up to a centimetre or more in diameter). (Fig. 8.)

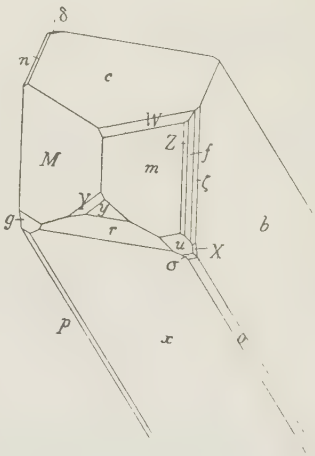

Fig. 8.—Albite from Haddam Neck.

Twinning upon the albite-law is very frequent, but no other kinds of twinning have been observed.

The cleavage-angle bc, obtained from the measurement of a twin-crystal, is 86° 26½′.

The following forms are present:—

b {010}, c {001}.
m {110}, *Z {120}, f {130}, ζ {150}, M {1$\bar{1}$0}.
x {$\bar{1}$01}, r {$\bar{4}$03}, y {$\bar{2}$01}.
n {0$\bar{2}$1}.
u {22$\bar{1}$}, σ {44$\bar{3}$}, o {11$\bar{1}$}, δ {11$\bar{2}$}, *X {24$\bar{1}$}.
g {2$\bar{2}$1}, p {1$\bar{1}$1}, *Y {3$\bar{1}$1}, *W {111}.

Of these, *W*, *X*, *Y*, *Z*, do not seem to have been previously recorded; their existence is inferred from the following measurements :—

	Limits.	Edges.	Mean.	Calculated (Dana).	
mW 110 : 111	32° 29′ to 33 51′ rounded	1	33° 10′	32° 28′	Rounded face on edge c/m (on 1 crystal).
yX 201 : 2$\bar{4}$1	52° 57′–53° 40′	2	53 18½	52 56	Narrow face on edge b'/u (on 3 crystals).
uX 2$\bar{2}$1 : 2$\bar{4}$1	—	1	19 51	20 7½	
cX 001 : 2$\bar{4}$1	—	1	87 58	87 52	
bX 010 : 24$\bar{1}$	—	1	39 8	39 24	
yY 201 : 3$\bar{1}$1	—	1	16 12	16 18	Small bright face on edge y/M' (on 1 crystal).
bZ 010 : 120	—	1	[40 46]	41 21	Very narrow face in zone [b m] (on 1 crystal) [reading by max. illumination].

The mean extinction angles for Na light are :—

on $c\,(001) = 3\frac{1}{2}°$
on $b\,(010) = 19\frac{1}{2}°$.

Good specimens, consisting of aggregations of thin tabular crystals thickly covered with spherules of cookeite, are also found.

Beryl.

The Oxford collection contains four specimens of beryl, which belong to two types. The first of these is represented by three incomplete, and mostly semi-opaque, crystals consisting of a pale rose-pink outer layer (which is occasionally transparent), and a greenish-white core. They have the form of hexagonal prisms, m $\{10\bar{1}0\}$, terminated by the basal plane, and bearing faces of a pyramid, s $\{11\bar{2}1\}$ on the corners. They range up to 8 cm. in diameter, and are remarkable for the possession of fairly perfect cleavages, parallel to m $\{10\bar{1}0\}$ and c $\{0001\}$, and sometimes enclose crystals of albite and tourmaline. To the second type belongs a nearly colourless crystal, about 2 cm. in diameter, embedded among grey quartz crystals. It is almost devoid of smooth faces and difficult to decipher, but an acquaintance with the British Museum specimen described below, leads to the recognition

of its two bright faces as belonging to m {10$\bar{1}$0}, while the dull, rough faces probably belong to s {11$\bar{2}$1}, n {31$\bar{4}$1}, p {10$\bar{1}$1}. The basal plane c {0001} is probably also present, but is almost hidden by the surrounding quartz crystals. The habit differs somewhat from the crystal figured, being flat-pyramidal owing to the reduction of the prism faces to small rhombs bounded by n {31$\bar{4}$1}.

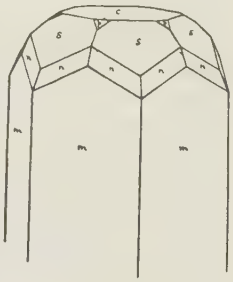

Fig. 9.—Beryl from Haddam Neck.

In the British Museum are two specimens of beryl from Haddam Neck, which are both labelled as containing caesium [1]. One of these is a large, stout prism of very pale pink colour, corresponding to the first type, and enclosing small prisms of the usual tourmaline and a small fragment of a brown mineral, probably garnet. The other, which represents the second type, is a nearly colourless hexagonal prism (fig. 9), 1·5 cm. in diameter and 2·5 cm. long, with pyramid faces, associated with grey quartz, white microcline, pink and green tourmaline and albite, on 'graphic' microcline-pegmatite. The faces belong to the following forms:—

Dana.		Miller.
m {10$\bar{1}$0}	. . .	a {10$\bar{1}$}
c {0001}	. . .	o {111}
s {11$\bar{2}$1}	. . .	r {100, $\bar{1}$22}
n {31$\bar{4}$1}	. . .	– {203, 423}
p {10$\bar{1}$1}	. . .	p {120}

The basal plane is very uneven, with ridges and pits, but bright; the prism is smooth and brilliant; of the pyramids, s is somewhat pitted, while n is usually dull but with some bright areas. The faces of the latter form generally show a rounding-off in the direction of s. The form p only occurs as minute triangular faces on the corners *scs*. The crystal resembles the colourless beryl known as 'goshenite' from Goshen, Massachusetts.

Quartz.

Quartz occurs both in nearly colourless and in somewhat smoky crystals: those of the former variety are curiously flattened parallel to a pair of

[1] Mr. Lazard Cahn, through whom the specimens were obtained, informs me that they were tested by Prof. Penfield and found to contain caesium.

prism faces. Only one side of such tabular crystals has the faces regularly developed, the faces at the back being interrupted, uneven, and drusy, with the result that the specimens (though frequently doubly terminated and bounded on all sides by faces) present the appearance of flakes split off from the side of a large normally developed crystal.

The smoky crystals are regular prisms with pyramidal termination, the faces of which are sometimes rhombohedrally developed. The surface of the crystals is often encrusted with cookeite.

Cookeite.

Small globular masses (up to 5 mm. diam., but usually not above 1 mm.) occur, having the following characters. They are of a yellowish-white colour and are composed of silvery radial plates with hexagonal outline. These are seen under the microscope to be divided radially into biaxial sectors, each striated perpendicular to the edge of the hexagon, and showing a normally emergent bisectrix of wide axial angle, with axial plane perpendicular to the striations and positive birefringence. The axial angle diminishes towards the centre, and the central part is uniaxial, with the optic axis normal and weak positive double refraction. These characters agree with those of cookeite as given by Penfield[1].

The cookeite occurs chiefly on the surface of albite and quartz crystals and on the prisms of lepidolite. It does not seem to occur much on the tourmaline, and where it does so the surface of the latter underneath is quite fresh and smooth, so that the cookeite would not here appear to have been derived from the decomposition of rubellite, as has been suggested by Brush[2] in regard to cookeite from Hebron and Paris, Maine.

The minerals are so intimately mixed that it is hard to say of what the cookeite is a decomposition product, but it may be perhaps derived from the micas.

The blowpipe characters agree with those given for cookeite.

Fluor.

The fluor is dark reddish-brown, and sometimes shows faces of the octahedron. None of the fragments show any of the matrix.

[1] Amer. Journ. Sci., 1893, ser. 3, vol. xlv, p. 393.
[2] Ibid. 1866, ser. 2, vol. xli, p. 247.

Besides this brown variety, I have recently seen a specimen consisting of small pale-green, opaque, somewhat drusy octahedra (4 mm. diam.) showing a purplish tinge in parts, associated with spherules of cookeite and a few fibres of the pink muscovite.

Microlite.

I have had no opportunity of seeing specimens of the microlite, as there is none in the Oxford collection and it is also wanting in the British Museum. Mr. Schernikow, however, says that it was found 'sparingly, associated with the other minerals. A few good crystals, perhaps $\frac{1}{4}$ inch in diameter, were obtained, but most of them were broken.'

Mr. Cahn tells me that the mineral was identified as microlite by Professor Penfield, and that the specimens occur in the pink beryl or in albite.

Columbite.

Columbite is stated to occur in the Haddam Neck quarries in association with beryl. The crystals are small but well defined, with brilliant faces, and differ thus from the columbite from Haddam, where the crystals are usually large and coarse.

Mode of Occurrence and Paragenesis.

In their mode of occurrence and characters some of the minerals from Haddam Neck show a remarkable resemblance to those from the well-known occurrences in the pegmatite veins of Maine and other parts of New England. The large crystals of muscovite surrounded by a border of lepidolite, for example, correspond exactly with similar specimens from Auburn, and some of the latter show, outside the lepidolite, a small amount of a rhombic tesselated mica similar to the pink fibrous muscovite which forms such a marked feature of the Haddam Neck specimens.

The regular intergrowth of greenish-white muscovite with massive quartz, which is visible on more than one of the specimens from Haddam Neck, finds its exact equivalent in a specimen in the British Museum, showing beryl from Goshen, Massachusetts. The beryl on the same specimen (the colourless 'goshenite') also strongly resembles the same mineral from Haddam Neck, the presence of caesium in which indicates an affinity with the beryls of Norway and Hebron in Maine, in which from 1·66–3·6 per cent. of Cs_2O have been found by Penfield and Harper and by Wells, respectively.

Judging from the relative positions of Haddam and Haddam Neck and from the information I have been able to obtain, it seems probable that the pegmatite veins traversing gneiss, which are the source of the minerals in both places, form part of the same system, though the minerals from the recently opened felspar quarries on Haddam Neck differ somewhat from those of the old occurrences described as Haddam. Thus the tourmaline from the latter occurs as stout black prisms, and the well-known chrysoberyl of Haddam does not seem to have been so far discovered at the new quarries, although it is mentioned as having been found on both banks of the river [1].

In regard to the order of formation of the minerals but little can be said, as the different species are intimately mixed together in a way which suggests that they were all formed more or less contemporaneously. The quartz was probably one of the last-formed minerals, as it frequently encloses complete crystals of tourmaline and masses of the pink fibrous mica. It forms in some cases a pegmatitic intergrowth with microcline, and sometimes also encloses flakes of greenish muscovite in parallel position, forming a somewhat analogous structure. The micas perhaps represent an early stage in the crystallization. Among themselves they never show any deviation from the order, greenish-white muscovite—lepidolite—fibrous muscovite. Minute scales of lepidolite, dispersed through the apatite crystals, are found after solution of the latter in acid. Microcline is probably a late formation, contemporaneous with the quartz, and sometimes encloses tourmaline and lepidolite.

In conclusion, I wish to express my thanks to Mr. Schernikow for his kindness in supplying me with information as to the locality and occurrence of the specimens, to Professor Berwerth for allowing me to examine the collection of micas in the Museum at Vienna, and to Mr. Fletcher for similar permission in respect of the specimens in the British Museum. I also wish to thank Professor Penfield for kind hints in connexion with the analysis, and Professor Miers for his kind advice throughout the work.

[1] Amer. Journ. Sci., 1822, ser. 1, vol. iv, p. 53; 1823, ser. 1, vol. vi, p. 220.

DESCRIPTION OF FIGURES 1-5 (PLATE IV).

Fig. 1.—Cleavage flake of the pink tesselated muscovite, showing the arrangement of the rhombs in twin position ($\times 14$).

Fig. 2.—A fibre of the pink muscovite. (The convergence of the faces is exaggerated.) $\pi = \{552\}$, $S = \{551\}$.

Figs. 3 and 4.—Flakes from crystals of muscovite with border of lepidolite (M, muscovite; L_m, macrodiagonal-; and L_b, brachydiagonal-lepidolite). The areas are shaded parallel to their axial planes. Unshaded areas of the border do not extinguish, owing to overlapping.

Fig. 3 shows a narrow band of L_m in parallel position on M, with areas of L_b outside it ($\times 8$).

Fig. 4 shows L_m in parallel position, and L_b in twin-positions, on M ($\times 10$). $m = \{110\}$, $b = \{010\}$.

Fig. 5.—Flake from a crystal of macrodiagonal-lepidolite showing the arrangement of the fibrous border. $m = \{110\}$, $b = \{010,\}$ $Q = \{130\}$. The areas II are in the extinction-position ($\times 5$).

(Figs. 6–9 in the text.)

On the remarkable problem presented by the crystalline development of Calaverite.

By G. F. Herbert Smith, M.A., F.G.S.
With a Chemical Analysis by G. T. Prior, M.A., F.G.S.
Assistants in the Mineral Department of the British Museum.

[Read March 19 and June 18, 1901].

THE validity of Haüy's great law of the rationality of intercepts — better known as the law of rational indices—or its equivalent, the law of homogeneity of arrangement of the ultimate particles in a crystalline structure, has as yet never been seriously called into question: nevertheless, in the crystals of the telluride of gold, calaverite, we find characters which are to all appearance at variance with this law. As far as the author is aware and can ascertain, no difficulty of a precisely similar kind has ever been encountered before[1]. Certain substances do, indeed, display the so-called optical anomalies; but these are, as was first established by Mallard, in reality in strict accordance with the actual crystalline arrangement. In calaverite we are confronted with a problem of a different nature: here, if we pay attention merely to the morphological development of the faces, we immediately conclude that the crystals have the symmetry of the monoclinic system; there is evidently an axis of digonal symmetry parallel to the prism edge, and on many crystals a face may be noticed perpendicular to this edge, and, save in those which are obviously twins, there are no re-entrant angles[2] to suggest that the crystals are other than simple; their opacity prevents any optical investigation. When, however, we proceed to assign indices to the forms we find that with the exception of a few, to which by a suitable choice of the crystallographic axes and parametral plane we necessarily give simple indices, all the forms receive symbols of great

[1] The faces with high indices but simple mutual relations, lying in the same zone, in such a mineral as meneghinite may possibly be due to a similar cause, but in this case the common faces present no difficulties at all.

[2] Re-entrant angles do occur in the prism zone, but are due to its oscillatory and striated character.

and unsatisfactory complexity. So few, indeed, are the forms which receive anything approaching to simple indices that it is difficult to believe that this interpretation adequately represents the actual symmetry of calaverite. It will be shown in the course of this paper that the faces do possess zonal relations and do obey the law of simple anharmonic ratios in every zone, but they cannot be referred to a single lattice. In fact there appear to be as many as five distinct lattices, which are incongruent but not independent. The exact relations between them and the possible meaning of such a remarkable conjunction are discussed below (pp. 140–1).

Until quite recently practically nothing was known of the crystallographic characters of calaverite. The name was given by Genth [1] to a massive telluride of gold from the Stanislaus Mine, Calaveras County, California. The material from Cripple Creek, Colorado, analysed by Dr. W. F. Hillebrand, was, indeed, in part well crystallized, but so small and unsymmetrically developed were the crystals that Professor Penfield [2], to whom they were sent for examination, was unable to determine with certainty even the system of crystallization, and could only conclude that the crystals were probably triclinic and near sylvanite in their angles and axial ratios. Better material having since that time become available, Professor Penfield and Mr. W. E. Ford [3] have recently published a paper in which they place calaverite in the monoclinic system, but confess that the symbols which must be assigned to most of the faces are inexplicably high.

During the past two years and a half the Mineral Collection of the British Museum has been enriched by the acquisition, mainly through the kind consideration of Mr. Milton Moss, of a fine suite of specimens from the Cripple Creek District, Colorado. Conspicuous among these are numerous brilliant, yellowish crystals, which were stated to be calaverite. With the view of establishing their identity and determining the crystallographic characters of this mineral, a goniometric examination of the best crystals was begun by the author early in November, 1900, and continued almost without interruption for some months, during which time more material came to hand. The preliminary results of the investigation were discussed at the meetings of the Society held on

[1] Amer. Journ. Sci., 1868, ser. 2, vol. xlv, p. 314.

[2] 16th Annual Report U. S. Geol. Survey, 1894-5 (1895), pt. ii, pp. 135–6; also Amer. Journ. Sci., 1895, ser. 3, vol. l, p. 131.

[3] Amer. Journ. Sci., 1901, ser. 4, vol. xii, pp. 225–46; a German translation appeared in Zeits. Kryst. Min., 1902, vol. xxxv, pp. 430–51.

March 19 and June 18, 1901. The brief notice of the earlier meeting which appeared in 'Nature[1]' attracted the attention of Professor Penfield, and he communicated with the present writer, who in reply gave a more detailed account of his conclusions; in consequence a paragraph[2] referring to them was inserted in the paper of Penfield and Ford already mentioned.

In the course of this investigation measurements were made of no fewer than forty-nine crystals, of which nineteen were removed from the matrix for the purpose and thirty had been already isolated. Nine crystals were taken from a specimen stated to have come from the Midget Mine, Gold Hill; one from a specimen from the Doctor Jackpot Mine, Raven Hill, and fifteen isolated crystals came from the same mine; four isolated crystals came from the Victor Mine, Bull Hill; and eight isolated twin crystals from the Elkton Mine, Raven Hill: the exact localities of the remaining specimens are not stated on the labels. Twenty-six are what may be called simple crystals, and twenty-three are crystals twinned according to ordinary laws; of the twenty-six simple crystals seventeen are left-handed and nine right-handed, in the sense employed by Penfield and Ford. They are associated with quartz, iron-pyrites, fluor and kaolin, and are, when on the matrix, firmly embedded in the gangue. Consequently crystals terminated at both ends are exceedingly rare; indeed only one such instance was noticed, and that in the case of one individual of a cross twin; in another case, where faces occur at the lower end they really belong to the second individual of a twin. When fresh, the crystals are silver-white in colour, but become more or less deep bronze-yellow on exposure.

The crystals differ considerably in size but are very similar in appearance, the cross-section varying from a narrow oblong to a square (see figs. 1 and 2); those removed from the matrix are small, with a cross-section of about $0{\cdot}5 \times 0{\cdot}5$ mm., in the case of the smallest measured of $0{\cdot}2 \times 0{\cdot}2$ mm.; the isolated crystals are very much larger, some being as much as 7 mm. in length with a breadth varying from 1–5 mm. Many of the large crystals are skeletal, with a remarkable development of internal faces which are all consistent with the development of the exterior; it is not uncommon to find pits on a large face lined with faces in harmony with the crystalline development. Many crystals which, judged from the exterior, appear to be compact are found on fracture to be more or less hollow.

The crystals are prismatic in habit. The prism zone is so much

[1] Nature, 1901, vol. lxiii, p. 554. [2] Loc. cit., p. 241.

striated parallel to its edge that a definite single image rarely occurs corresponding to any particular face; the terminal faces, on the other hand, give good definite reflections in most cases, although many of the faces, even on the large crystals, are so minute that when viewed through the microscope of low power, into which the telescope of the goniometer may be converted, only a speck of light is visible and no certain contour is discernible. The figures, though intended to be representative, have been drawn from actual crystals; in figs. 1, 2, 4, 5, and 6 the line

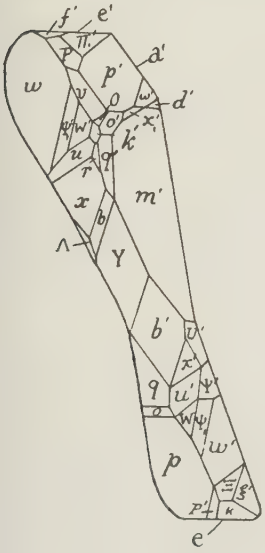

FIG. 1.

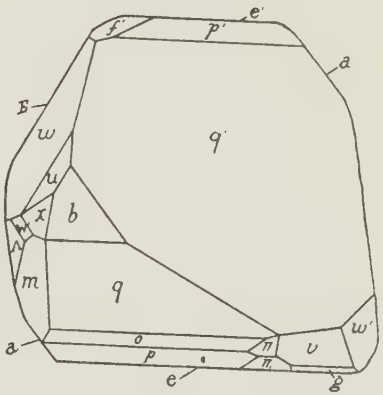

FIG. 2.

Untwinned crystals.

of sight is supposed to be parallel to the edge of the prism. The crystal drawn in fig. 1 has a cross-section of $3{\cdot}5 \times 0{\cdot}7$ mm. and possesses no fewer than sixty-two terminal faces representing forty-two different forms. Nearly half of these are so minute that it was impossible to include them in the drawing. The proportionate size even of the smaller faces given in the figure had necessarily to be somewhat exaggerated. This figure is typical of all those with many faces; a few faces, such as *f*, *o*, *q*, *b*, *y*, &c., are comparatively large, but the remainder, situated at the edges or on the corners of the large faces, are almost infinitesimal in size; nevertheless they give measurable, if very faint, images. The crystal drawn in fig. 2 has a cross-section of $2{\cdot}2 \times 2{\cdot}2$ mm. It is

remarkable for the unusual number of definite faces in the prism zone which give distinct images.

The crystals are very brittle, but exhibit no cleavage. Their fragility is so great that many of the isolated crystals are broken in parts (cf. figs. 4, 5, and 6).

In carrying out the examination of these complex crystals the author had at his disposal an instrument conveniently adapted to the purpose in the three-circle form of goniometer[1] designed by him, whereby the zonal relations of the terminal forms can be determined by direct observation. It may here be repeated that the method of using this instrument is to adjust the edge of some prominent zone—in this case the prism zone—parallel to the axis of the third circle, C[2], and to make measurements from any pole in this zone which is crystallographically possible, but does not necessarily represent an existing face. For any terminal face the readings of the circles A and B, duly corrected for the zero reading, give respectively the polar distance and the azimuth. The azimuths when measured from such a pole must, in the case of a simple crystal, obey the law of rational anharmonic ratios, and we have, therefore, a convenient method of determining the indices of any terminal face as the intersection of two known zones.

As has been already stated, the prism zone of calaverite is invariably striated; this, of course, does not in any way prevent, but on the contrary tends to facilitate, the accurate adjustment of its edge parallel to the axis of C. On the other hand, no face is found to give a sufficiently well defined image which can invariably serve as pole of reference, and any such pole had to be determined from the intersection of a cross zone with the prism zone. Fortunately there happens to occur on all the measured crystals, with the exception of a few cross twins, a markedly prominent zone, which contains at least two, and usually three or four, well developed faces, giving bright and distinct reflections. The adjustment of this zone could, therefore, be made with considerable certainty, and, indeed, whenever it was deemed necessary to re-measure any crystal, there was very close agreement between the two sets of readings; any discrepancy is generally due to a slight want of parallelism in the prism zone, or, if it occurs in a few particular readings, to a want of definition

[1] This Magazine, 1899, vol. xii. pp. 175–82; a translation appeared in the Zeits. Kryst. Min., 1900, vol. xxxii, pp. 209–16. Cf. also this vol., p. 75.

[2] This is the same notation as that employed in the papers mentioned above: A is the horizontal circle, whose axis is fixed in space; B the vertical circle, whose axis lies in a horizontal plane; and C the third circle, whose axis may take any direction in space.

in the reflected images. Unless the corresponding image is much striated any reading may be regarded as accurate within 5′; a point to which we refer later. The point of intersection of the above-mentioned zone with the prism zone served as pole of reference for the whole of the crystals measured, with the exception of the twins alluded to. These measurements are given in Table I.

In this table the whole of the observations made on forty-two crystals are incorporated, and have been duly weighted in deducing the mean values; the remaining seven crystals examined, all cross twins, do not possess the particular cross zone sufficiently well developed for the accurate determination of the pole of reference. The symmetry revealed by the measurements is discussed later, but we may mention here that the fundamental constants and the indices of the forms have been calculated by the method of least squares, from the angles marked with an asterisk, on the hypothesis that the symmetry is triclinic, and becomes pseudo-monoclinic owing to twinning about an axis parallel to the edge of the prism zone. The symbols given in the first column are the indices which the faces receive when referred to the principal lattice, on which most of the large and prominent faces lie. Many which receive complex indices, when referred to this lattice, have simple indices, when referred to a second; these symbols are given in the second column. As will be seen below, a few, such as Y and μ, which cannot be referred to either of these lattices, lie on a third. The prism zone is common to all three. The constants of the second lattice are computed from the calculated values in Table I; those of the third lattice from the values calculated for the prism zone and from the mean observed azimuth and distance of J, namely, 90° 0′ and 105° 11′½.

The fundamental constants of the three lattices are :—

$\mathbf{T_1}$. First and principal (triclinic) lattice :

$$a : b : c = 2{\cdot}0013 : 1 : 1{\cdot}1713;$$

$$a = 83° 58′,\ \beta = 100° 39′,\ \gamma = 96° 19′;$$

$$010 : 001 = 94° 59′,\quad 001 : 100 = 79° 54½′,\quad 100 : 010 = 84° 41′.$$

$\mathbf{T_2}$. Second (triclinic) lattice :

$$a : b : c = 2{\cdot}0990 : 1 : 1{\cdot}2231;$$

$$a = 72° 14′,\ \beta = 104° 48′,\ \gamma = 108° 37′;$$

$$010 : 001 = 104° 7′,\quad 001 : 100 = 79° 54½′,\quad 100 : 010 = 74° 48½′.$$

$\mathbf{M_3}$. Third (monoclinic) lattice :

$$a : b : c = 1{\cdot}9868 : 1 : 1{\cdot}1634;$$

$$\beta = 100° 5½′.$$

TABLE I.

Measurements from *e* (101).

Form.				Calculated Values.		Observed Means.		Edges.	Limits of Observation.			Remarks. Characters of faces and images.
	T_1	T_2	M_3	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.		Distance.	
				° ′	° ′	° ′	° ′		° ′	° ′	° ′ ° ′	
e	101	...	...	0 0	0 0	0 0	0 1	33	...	...	359 41 – 0 30	Small; image distinct.
e_1	705	...	...	,, ,,	7 36½	,, ,,	7 35	2	...	...	7 23, 7 47	Striated.
e_2	302	...	...	,, ,,	9 15	,, ,,	?	...	...	...	10° – 17°	,,
e_3	201	...	...	,, ,,	16 8							
e_4	401	...	...	,, ,,	30 57	,, ,,	?	...	...	...	30° – 38°	,,
e_5	501	...	...	,, ,,	34 42							
a	100	...	...	,, ,,	52 18½	,, ,,	52 28	42	...	...	51 30 – 53 9	Often large; single image.
E_{12}	10.0.$\bar{1}$	...	...	,, ,,	62 8	,, ,,	62 11½	8	...	...	61 20 – 62 38	Striated.
E_{11}	60$\bar{1}$	...	...	,, ,,	68 44	,, ,,	69 7	42	...	...	68 15 – 69 58	,,
E_{10}	25.0.$\bar{6}$	...	...	,, ,,	75 48	,, ,,	75 54	3	...	...	75 42 – 76 11	,,
E_9	11.0.$\bar{3}$	...	...	,, ,,	78 50½	,, ,,	78 41	10	...	...	78 1 – 79 32	,,
E_8	30$\bar{1}$	...	...	,, ,,	84 13							
E_7	502	...	...	,, ,,	89 41	,, ,,	?	...	...	...	84° – 96°	Much striated and oscillatory.
E_6	20$\bar{1}$	...	...	,, ,,	96 58½							
E_5	903	...	...	,, ,,	100 33	,, ,,	101 0	16	...	...	99 58 – 102 42	Striated.
E_4	70$\bar{1}$	...	...	,, ,,	101 31							
E_3	807	...	...	,, ,,	115 40	,, ,,	115 20	5	...	...	114 39 – 115 53	,,
E	10$\bar{1}$	...	...	,, ,,	119 40½	,, ,,	119 19½	24	...	...	118 11 – 120 6	Distinct face and image.
E_1	30$\bar{1}$	...	...	,, ,,	127 18	,, ,,	127 5½	8	...	...	125 48 – 127 52	Striated.
E_2	103	...	...	,, ,,	141 8½	,, ,,	140 28	6	...	...	140 13 – 140 51	,,
c	00$\bar{1}$	...	...	,, ,,	152 24	,, ,,	152 18	44	...	...	151 24 – 152 40	Small; image distinct.
e_7	10$\bar{2}$	...	...	,, ,,	167 44	,, ,,	?	...	...	...	168° – 171°	Striated.
e_6	7.0.$\bar{12}$	...	...	,, ,,	170 0							

η	[illegible]	...	...	21 19	69 25	21 9	69 18	1	... ...	... ...	Small; image good.
β	69.20.5	310	...	31 28½	65 53	31 38	66 2	2	31 37, 31 39	65 59, 66 5	Small; images good.
χ	310	...	...	36 30½	61 33½	36 32½*	61 40	1	... ...	... ...	Small; image good.
γ	52$\bar{1}$	...	...	,, ,,	77 39½	,, ,,	77 55	1	... ...	... ...	Minute; image poor.
σ	21$\bar{1}$	...	...	,, ,,	95 56	,, ,,	96 1	1	... ...	... ...	,, ,,
ξ	323	...	...	,, ,,	113 6½	,, ,,	113 2½	6	36 20–36 42	112 43–113 15	Small; images distinct.
w_1	11$\bar{2}$	...	...	,, ,,	126 51½	...	...	...	... ...	... ...	See Table III.
ρ_1	59.20.5	521	...	39 7	55 32	39 12	55 11	1	... ...	... ...	Minute; image poor.
ρ	49.20.5	210	...	,, ,,	71 1	39 9	71 1	12	38 22–39 25	70 42– 71 54	Small; images distinct.
Z	39.20.$\bar{1}$5	32$\bar{1}$	...	,, ,,	89 54	39 12	89 52	2	39 0, 39 24	89 50, 89 54	Minute; images poor.
K	29.20.25	11$\bar{1}$	...	,, ,,	108 48	39 0	108 45	1	... ...	... ...	,, image poor.
K_1	19.20.35	123	...	,, ,,	124 19½	...	...	...	... ...	... ...	Not observed; a possible plane of twinning.
a	521	...	...	46 34	50 22	46 30½*	50 27	1	46 13–46 48	... ...	Minute; image poor.
ϕ	210	...	...	,, ,,	66 31½	,, ,,	66 33	9	,, ,,	66 11– 66 59	Small; images distinct.
θ	32$\bar{1}$	...	...	,, ,,	87 41½	,, ,,	87 47½	9	,, ,,	87 20– 88 7	,, ,,
w	11$\bar{1}$	...	...	,, ,,	109 28½	,, ,,	109 27½	51	,, ,,	109 11–109 48	Common face: usually small; images good.
Δ	39.20.5	321	...	50 27½	59 7	50 35	59 21½	2	50 14–50 49	59 18, 59 25	Minute; images poor.
Λ	29.20.5	110	...	,, ,,	79 48½	,, ,,	79 27	7	... ...	79 5– 79 56	Small; images fair.
Ψ	19.20.$\bar{1}$5	12$\bar{1}$	...	,, ,,	103 25	,, ,,	103 35	7	... ...	103 23–103 40	,, ,,
R_3	11.6.3	...	...	55 53	52 20	54 35	52 20	1	... ...	... ...	Minute; image poor.
R_2	531	...	...	,, ,,	58 6½	,, ,,	59 10	1	... ...	... ...	,, ,,
R_1	563	...	...	,, ,,	97 12½	55 0	96 26½	5	54 48–55 19	96 20– 96 31	Small; images fair: indices uncertain.
R	23$\bar{2}$	...	...	,, ,,	105 26	55 55	105 31	1	... ...	... ...	Minute; image poor.
d_1	211	...	...	61 30½	36 12½	61 31½*	37 0	1	61 12–61 50	... ...	Minute; image bad.
d	321	...	...	,, ,,	53 57	,, ,,	54 2½	15	,, ,,	53 50– 54 15	Small; images distinct.
τ_1	541	...	...	,, ,,	63 55	,, ,,	63 15	1	,, ,,	... ...	Minute; image bad.

K

TABLE I (*continued*).

Measurements from *e* (101).

Form.				Calculated Values.		Observed Means.		Edges.	Limits of Observation.		Remarks. Characters of faces and images.
	T_1	T_2	M_3	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.	
				° ′	° ′	° ′	° ′		° ′ ° ′	° ′ ° ′	
m	110	...	...	61 30½	75 54	61 31½	75 54*	63	61 12 – 61 50	75 29 – 76 25	Very common and large; images
τ	34$\bar{1}$	...	...	,, ,,	89 16½	,, ,,	89 34	1	,, ,,	... ...	Minute; image poor. [good.
n	12$\bar{1}$	...	...	,, ,,	102 43	,, ,,	102 38½	39	,, ,,	102 28 – 102 56	Common and fairly large; images
n_1	14$\bar{3}$	...	...	,, ,,	114 53	,, ,,	113 10	1	,, ,,	... ...	Minute; indices doubtful. [good.
M	01$\bar{1}$	...	...	,, ,,	125 5	,, ,,	125 5	17	,, ,,	124 54 – 125 18	Small; images fair.
ω	29.20.15	111	...	67 8½	47 10½	67 29½	47 10	8	66 44 – 69 9	46 32 – 47 26	Small; images poor.
x_1	19.20.5	121	...	,, ,,	66 52½	,, ,,	66 53	2	,, ,,	66 45, 67 1	Minute; ,,
x	9.20.5	010	...	,, ,,	94 10	,, ,,	94 8½	26	,, ,,	93 24 – 94 36	Common and fairly large; images
X	1.20.15	12$\bar{1}$	...	,, ,,	119 48	,, ,,	119 54	3	,, ,,	119 44 – 120 0	Minute; images poor. [fair.
Ω	11.20.25	11$\bar{1}$	...	,, ,,	137 0½	,, ,,	136 55	3	,, ,,	136 35 – 137 15	,, ,,
N_2	471	...	...	72 41	75 56½	72 12	76 13	1	... ...	... ...	,, image bad.
N_1	370	...	...	,, ,,	84 9	73 13	85 8	1	... ...	... ...	,, ,,
N	47$\bar{7}$	...	...	,, ,,	133 1½	72 55	133 30	1	... ...	... ...	,, ,,
i	323	...	...	82 6½	32 14	82 7½	32 14½	13	81 30 – 82 40	32 3 – 32 40	Small; images poor.
p	111	...	...	,, ,,	43 38½	,, ,,	43 39*	76	,, ,,	43 17 – 44 2	Very common and large; images
n	343	..	...	,, ,,	52 3	,, ,,	52 5	2	,, ,,	51 55, 52 15	Small; images fair. [good.
o	121	...	...	,, ,,	62 55½	,, ,,	62 55*	61	,, ,,	62 11 – 63 43	Very common and large; images good. [good.
q	141	...	...	,, ,,	76 22	,, ,,	76 21½*	60	,, ,,	76 0 – 76 36	Very common and large; images
l	161	...	...	,, ,,	81 18½	,, ,,	81 14	1	,, ,,	... ...	Minute; image poor. [usually good.
b	010	...	...	,, ,,	91 30	,, ,,	*91 30½	57	,, ,,	91 3 – 92 15	Very common and large; images

L	161	...	...	,, ,,	101 36	,, ,,	101 22	2	,, ,,	101 16, 101 28	Minute; images poor.
Q	141	...	...	,, ,,	106 25½	,, ,,	106 25½	7	,, ,,	106 12–106 39	,, images fair.
y	121	...	...	,, ,,	119 24	,, ,,	119 27	20	,, ,,	119 17–119 54	Small; ,,
P	111	...	...	,, ,,	137 45	,, ,,	137 45	12	,, ,,	137 11–137 53	,, ,,
I	323	...	...	,, ,,	148 36	,, ,,	148 30	2	,, ,,	148 25, 148 35	Minute; images poor.
A	5.32.3	...	...	87 50½	90 9½	87 27	90 26	4	87 18–87 40	90 14– 90 33	,, ,,
Π_2	29.20.35	112	...	89 0	29 21	89 6	29 30	1	88 24–90 0	... ...	,, image poor.
Π_1	19.20.25	123	...	,, ,,	38 58½	,, ,,	39 2	4	,, ,,	38 42– 39 12	Small; images fair.
Π	9.20.15	011	...	,, ,,	55 15½	,, ,,	55 26½	7	,, ,,	54 47– 55 37	,, ,,
ψ	1.20.5	121	...	,, ,,	81 24½	,, ,,	81 38	6	,, ,,	81 15– 82 14	Minute; images poor.
λ	11.20.5	110	...	,, ,,	111 22	,, ,,	111 27	2	,, ,,	111 26, 111 28	,, ,,
δ	21.20.15	321	...	,, ,,	133 2	,, ,,	132 52	2	,, ,,	132 40, 133 4	,, ,,
π	31.20.25	211	...	,, ,,	145 53	...	...	...	... ..	... ...	Given by Penfield and Ford.
Y	5.24.3	...	010	89 46½	89 42½	90 0[1]	90 0[1]	23	90 12	90 8	Common and large; images good.
J	11.24.3	...	141	,, ,,	104 54	,, ,,	105 11½	6	... ...	105 4–105 16	Minute; images fair.
O_1	141	...	...	93 37½	84 56½	93 22	85 5	1	... ...	... ...	Minute; image poor.
O	120	...	...	,, ,,	100 19½	93 30	100 17	1	... ...	... ...	,, ,,
C_1	9.10.15	...	...	95 55½	35 24½	96 1	35 37	1	95 10–96 48	... ...	,, ,,
C_2	4.15.5	...	...	,, ,,	81 39½	,, ,,	82 14	2	,, ,,	82 8, 82 20	,, images poor.
C	350	...	...	,, ,,	102 0½	,, ,,	102 11	9	,, ,,	101 35–102 23	Small; ,,
C_3	41.60.5	...	...	,, ,,	106 52½	,, ,,	106 57	2	,, ,,	106 53, 107 1	Minute; ,,
C_4	26.35.5	...	...	,, ,,	110 11	,, ,,	110 12	1	,, ,,	... ...	,, image poor.
C_5	11.10.5	...	...	,, ,,	126 59	,, ,,	127 15	1	,, ,,	... ...	,, ,,
C_6	27.20.15	...	...	,, ,,	135 39½	,, ,,	135 22	1	,, ,,	... ...	,, ,,
H_1	142	...	...	99 20	74 27½	98 52	74 24	1	... ...	... ...	,, ,,
H_2	11.16.1	...	...	,, ,,	100 46½	98 51	100 48	2	98 50, 98 52	100 47, 100 49	,, images poor.
H	340	...	...	,, ,,	104 25½	99 40	104 46	2	99 30, 99 50	104 40, 104 52	,, ,,

[1] The mean values of the co-ordinates of *Y* cannot be determined because there is no possibility of ascertaining whether a measurement is greater or less than a right angle.

TABLE I (*continued*).

Measurements from *e* (101).

Form.				Calculated Values.		Observed Means.		Edges.	Limits of Observation.		Remarks. Characters of faces and images.
	T_1	T_2	M_2	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.	
				° ′	° ′	° ′	° ′		° ′ ° ′	° ′ ° ′	
h_1	7·15·5	...	...	100 27½	85 12	99 57	85 49	1	... ...	... ...	Minute; image poor.
h	$\bar{4}50$	...	...	,, ,,	105 12	100 43	105 6	2	100 40, 100 46	104 32, 105 40	,, images poor.
h_2	$\bar{1}3·10·5$	...	...	,, ,,	128 50½	100 50	128 30	1	... ...	... ...	,, image poor.
ϵ	$\bar{1}\bar{1}·24·9$	...	$\bar{1}41$	101 12	83 16½	101 19½	82 7	1	101 5 – 101 40	... ...	,, image poor.
μ	$\bar{1}7·24·3$	...	$\bar{1}20$	,, ,,	98 25½	,, ,,	98 40½	19	,, ,,	98 31 – 98 47	Small; images fair.
ζ	$\bar{2}3·24·3$	...	$34\bar{1}$	,, ,,	112 30	,, ,,	112 50	3	,, ,,	112 40 – 112 55	Minute; ,,
f	112	...	...	104 52	29 28	104 51½*	29 30	25	104 24 – 105 35	29 5 – 29 42	Small; images good.
g	123	...	...	,, ,,	38 45½	,, ,,	38 48½	11	,, ,,	38 37 – 39 3	,, images fair.
v	011	...	...	,, ,,	54 11½	,, ,,	54 17	6	,, ,,	54 12 – 54 24	,, ,,
r	$\bar{1}21$	...	...	,, ,,	78 51½	,, ,,	78 48½	23	,, ,,	78 20 – 79 4	,, ,,
r_1	$\bar{4}51$	...	...	,, ,,	96 37½	,, ,,	96 35	1	,, ,,	... ...	Minute; image poor.
t	$\bar{1}10$	...	...	,, ,,	108 7½	,, ,,	107 58	23	,, ,,	107 25 – 108 22	Common, but not large; images fair.
D	$32\bar{1}$	...	...	,, ,,	130 25½	,, ,,	130 18	3	,, ,,	130 4 – 130 27	Small; images poor.
k_2	9·20 35	012	...	111 8	36 10½	111 24½	36 15	1	110 33 – 112 30	... ...	Minute; image fair.
k_1	$\bar{1}·20·25$	$\bar{1}23$	...	,, ,,	49 15	,, ,,	49 30½	4	,, ,,	49 22 – 50 0	,, images poor.
k	$\bar{1}\bar{1}·20·15$	$\bar{1}11$	...	,, ,,	70 25	,, ,,	70 30½	14	,, ,,	69 55 – 71 10	Small; images fair.
z	$\bar{2}1·20·5$	$32\bar{1}$	...	,, ,,	98 33	,, ,,	98 10	10	,, ,,	97 27 – 98 50	,, ,,
z_2	$\bar{1}3·10·0$	$74\bar{1}$	...	,, ,,	111 58	,, ,,	110 45	1	,, ,,	... ...	Minute; image poor.
z_1	$3\bar{1}·20·5$	$\bar{2}10$	...	,, ,,	123 16½	,, ,,	124 5	1	,, ,,	... ...	,, ,,

V_1	340	...	...	115 4	73 54	114 55	73 59	1	... ...	... ...	,,	,,		
V	785	...	...	,, ,,	80 32	115 45	81 10	1	... ...	... ...	,,	,,		
U_1	687	...	...	117 28	69 44½	117 47	70 17	3	117 38 – 117 56	70 10 – 70 29	,,	images poor.		
U	984	...	...	,, ,,	89 33½	116 36	89 27½	2	116 25, 116 47	89 25, 89 30	,,	,,		
T	332	...	...	118 8	81 9½	118 47	80 31	1	... ...	... ...	,,	image good.		
G_1	$\bar{1}47$	...	...	123 48	43 57½	123 47*	44 20	1	123 18 – 124 41	... ...	,,	image poor.		
G	$\bar{1}23$	...	...	,, ,,	50 56½	,, ,,	51 10	1	,, ,,	... ...	Small;	,,		
W	$\bar{1}11$	...	...	,, ,,	70 10	,, ,,	70 11	12	,, ,,	69 51 – 70 25	,,	images fair.		
W_1	876	...	...	,, ,,	76 56½	,, ,,	77 14	1	,, ,,	... ...	Minute;	image poor.		
Θ	321	...	...	,, ,,	95 9	,, ,,	94 53½	7	,, ,,	94 35 – 95 14	Small;	images fair.		
Φ	$\bar{2}10$	...	...	,, ,,	118 24½	,, ,,	118 19½	9	,, ,,	117 30 – 118 37	,,	,,		
Ψ_1	$\bar{2}9.24.27$	...	$\bar{1}11$	128 48	70 3½	129 0	70 16½	4	128 58 – 129 4	70 11 – 70 21	Small;	images fair.		
Γ_1	$\bar{5}20$	...	...	131 4	121 19	131 55	119 23	1	... ...	... ...	Minute;	image poor.		
κ	$\bar{1}12$	...	...	137 2	50 33	136 43½	50 30	2	136 32 – 136 57	50 29, 50 32	Small;	images good.		
Ξ	$\bar{3}23$	...	...	,, ,,	65 38	,, ,,	65 41	2	,, ,,	65 40, 65 42	,,	,,		
Σ	$\bar{2}11$	...	...	,, ,,	85 15	,, ,,	85 10	1	,, ,,	... ...	Minute;	image fair.		
Γ	$\bar{5}21$	...	...	,, ,,	106 0	,, ,,	106 1	1	,, ,,	... ...	,,	,,		
Υ	$\bar{2}1.20.45$	325	...	140 4	48 22½	139 34	48 18	1	... ...	... ...	,,	,,		
ν	$\bar{1}5.4.1$	...	...	145 54½	119 22½	146 19	119 24	1	... ...	... ...	,,	,,		
F	$\bar{1}7.4.3$	...	...	152 0½	109 57½	...	...	1	... ...	... ...	See Table III.			

As has already been stated, the prism zone is considerably striated parallel to the edge of the zone, so much so that in some cases no reliable measurements are obtainable. A few crystals, however, do possess definite faces giving bright and distinct reflections: one of these is exhibited in fig. 2. From a consideration of the measurements on all the crystals we may be certain of the existence of the forms a (100), c (001), e (101), E ($\bar{1}01$); but in the remainder of the zone measurable images are rare, and it is doubtful what forms are represented. Certain parts of the zone give an almost unbroken band of light.

A glance at the table shows that there is considerable variation about the mean value even in the case of measurements on which most reliance may be placed. We have remarked above that this variation cannot be explained as entirely due to errors of adjustment or observation; it must, therefore, have a real existence, and is, moreover, in accordance with the observations of those who have studied the characters of crystals growing in a saturated solution [1].

For convenience of reference the letters employed by Penfield and Ford to denote the terminal forms have as far as possible been retained in this paper. A study of Table II will show what changes have been made. In this table the monoclinic symmetry and the orientation of these authors have been adopted. The distances are given from the face perpendicular to the edge of the prism zone, and the zero azimuth passes through m (110). The values of these coordinates given on the left-hand side have been computed directly from the calculated values in Table I; on the right-hand side they are taken from the paper of Penfield and Ford [2], the observed values being the means of all those given in the different tables [3]. The symbols on the left-hand side assigned to the forms have been derived by transformation, with some slight alteration in certain cases for the sake of the resulting simplification. Keeping the zone $[c, f, p, m, w]$ unchanged, and substituting for o (121) the indices (13·22·10) of Penfield and Ford, we arrive at the following equations of transformation from one system to the other:—

$$(\lambda\mu\nu) = (9l + 2m,\ 11m,\ l - m + 11n);$$
$$(lmn) = (11\lambda - 2\mu,\ 9\nu,\ -\lambda + \mu + 9\nu);$$

where lmn, $\lambda\mu\nu$ are the symbols of any form according as the symmetry

[1] Cf. H. A. Miers: 'On a New Method of Measuring Crystals, and its Application to the Measurement of the Octahedron Angle of Potash Alum and Ammonia Alum.' Report Brit. Assoc., 1894 (Oxford), pp. 654–5.

[2] Loc. cit., p. 243.

[3] Loc. cit., pp. 230 et seq.

TABLE II.—COMPARISON WITH THE OBSERVATIONS OF PROF. PENFIELD AND MR. FORD.

Constants: $a:b:c = 1{\cdot}6304:1:1{\cdot}1468$; $\beta = 90°\ 10'$ (calculated from Table I).
$a:b:c = 1{\cdot}6313:1:1{\cdot}1449$; $\beta = 90°\ 12\frac{2}{3}'$ (Penfield and Ford)[1].

Form.			Calculated from Table I.				Form.		Calculated Values.				Observed Means.				No.
	T_1	M	Azimuth.		Distance.				Azimuth.		Distance.		Azimuth.		Distance.		
			°	′	°	′			°	′	°	′	°	′	°	′	
m	110	110	0	0	31	$31\frac{1}{2}$	m	110	0	0	31	$30\frac{1}{2}$	0	0	31	29	34
μ	$\bar{1}7{\cdot}24{\cdot}3$	13·33·1	9	$33\frac{1}{2}$	13	59	μ	17·40·2	9	30	14	$28\frac{1}{2}$	9	58	14	22	2
								33·80·4	9	$47\frac{1}{2}$	14	24					
x_1	19·20·5	441	19	$56\frac{1}{2}$	32	4	e	441	19	35	33	5	20	21	32	10	1
								42·44·11	20	26	32	1					
t	$\bar{1}10$	7·11·2	24	9	23	17	t	13·20·4	23	$38\frac{1}{2}$	23	$32\frac{1}{2}$	23	48	23	14	10
q	141	17·44·8	32	42	15	$42\frac{1}{2}$	q	11·29·5	32	52	15	$30\frac{1}{2}$	32	44	15	37	10
ζ	$\bar{2}3{\cdot}24{\cdot}3$	20·33·10	37	$6\frac{1}{2}$	25	0	h	21·37·11	36	40	23	$30\frac{1}{2}$	36	40	23	19	1
ω	29·20·15	20·15·12	39	30	47	29	ω	20·15·12	40	26	47	8	40	16	47	12	1
o	121	13·22·10	47	$11\frac{1}{2}$	28	7	o	13·22·10	47	$30\frac{1}{2}$	28	18	47	4	28	5	40
n	343	11·14·10	52	15	38	38	n	11·14·10	52	12	38	$17\frac{1}{2}$	52	$13\frac{1}{2}$	38	41	3
p	111	111	54	46	46	52	p	111	54	48	46	$54\frac{1}{2}$	54	47	46	52	33
i	323	10·7·11	57	17	58	6	i	10·7·11	57	18	58	29	57	9	58	6	2
π	$\bar{3}1{\cdot}20{\cdot}\bar{2}\bar{5}$	658	61	$37\frac{1}{2}$	55	53	π	22·18·27	60	5	56	31	59	46	56	10	1
f	112	112	70	29	61	37	f	112	70	29	61	40	70	21	61	$36\frac{1}{2}$	2
							g_1	10·15·22	71	36	52	38	72	6	52	49	1
g	123	4·7·10	73	52	52	46	g	4·7·10	74	7	52	22	73	53	52	46	1
y	$\bar{1}2\bar{1}$	5·22·14	75	56	30	21	y	296	76	38	30	54	76	26	30	$27\frac{1}{2}$	7
v	011	2·11·10	81	$48\frac{1}{2}$	38	23	v	2·11·10	81	48	38	$43\frac{1}{2}$	81	57	38	$20\frac{1}{2}$	4
k	$\bar{1}\bar{1}{\cdot}20{\cdot}15$	$\bar{1}0{\cdot}37{\cdot}22$	107	37	28	$30\frac{1}{2}$	k	$\bar{1}0{\cdot}32{\cdot}21$	108	18	31	6	108	27	31	3	1
r	$\bar{1}21$	5·22·8	114	$42\frac{1}{2}$	18	30	r	$\bar{1}0{\cdot}44{\cdot}15$	114	54	18	$10\frac{1}{2}$	114	41	18	28	9
w	$11\bar{1}$	$\bar{1}11$	125	1	46	48	w	$\bar{1}11$	124	55	46	$48\frac{1}{2}$	125	11	46	46	7
u	$12\bar{1}$	$\bar{1}3{\cdot}22{\cdot}12$	126	55	30	59	u	$\bar{1}\bar{1}{\cdot}18{\cdot}10$	127	32	31	28	127	$17\frac{1}{2}$	30	$58\frac{1}{2}$	10
K	29·20·$\bar{2}\bar{5}$	30·22·$\bar{2}\bar{7}$	128	$32\frac{1}{2}$	53	$19\frac{1}{2}$	j	756	129	$11\frac{1}{2}$	53	31	128	50	53	30	1
x	9·20·$\bar{5}$	$\bar{1}\bar{1}{\cdot}20{\cdot}6$	141	$36\frac{1}{2}$	23	13	x	$\bar{1}\bar{1}{\cdot}20{\cdot}6$	142	4	23	5	142	$22\frac{1}{2}$	22	53	5
							s	$\bar{1}\bar{1}{\cdot}62{\cdot}6$	142	4	7	50					
b	010	$\bar{2}{\cdot}11{\cdot}1$	141	$24\frac{1}{2}$	8	2	s_1	$\bar{2}{\cdot}11{\cdot}1$	144	28	7	47	142	$31\frac{1}{2}$	8	4	29
							σ	$\bar{2}{\cdot}10{\cdot}1$	144	28	8	33					
τ	$34\bar{1}$	$\bar{3}\bar{5}{\cdot}44{\cdot}12$	153	45	28	30	τ	$\bar{3}1{\cdot}38{\cdot}11$	153	8	29	14	153	16	28	55	1
z	$\bar{2}1{\cdot}20{\cdot}5$	$\bar{1}\bar{5}{\cdot}22{\cdot}1$	174	52	22	$43\frac{1}{2}$	z	$\bar{1}\bar{5}{\cdot}22{\cdot}1$	174	34	22	46	174	22	22	39	3
ρ	49·20·$\bar{5}$	$\bar{1}7{\cdot}9{\cdot}1$	176	$8\frac{1}{2}$	53	22	ρ	$\bar{4}\bar{4}{\cdot}21{\cdot}2$	176	18	52	9	176	32	52	45	1

[1] Loc. cit., p. 227.

is assumed to be triclinic or monoclinic. It will be noticed that there are two sets of the former corresponding to one of the latter, according to the sign given to the middle symbol.

To avoid the confusion due to the multiplicity of symbols, the following notation is adopted in this paper :—

(lmn) or (lmn) $\mathbf{T}_1$ are the indices of any form based on the first, the principal lattice ;

(lmn) $\mathbf{T}_2$ are those based on the second lattice ;

(lmn) $\mathbf{M}_3$ are those based on the third lattice ;

($\lambda\mu\nu$) $\mathbf{M}$ are those based on the monoclinic symmetry and orientation of Penfield and Ford.

There are two points which call for remark in Table II : the distance of k and the azimuth of π differ appreciably from the values calculated from Table I. The discrepancy is probably due to the difficulty of correctly determining the position of a faint and indistinct image. The form k has been observed fourteen times by the author, and there can be little doubt of its true position ; π has not been observed, but it falls very near a pole on the second lattice.

We may now return to the consideration of Table I. The positions of nearly all the forms recorded in that table are marked in fig. 3, which is a gnomonic projection on a plane perpendicular to the edge of the prism zone. The thick lines represent the zones of the principal lattice, and the thin lines those of the second lattice. The corresponding zones of the twin lattices are not drawn, to avoid complicating the diagram.

Almost without exception the terminal forms fall into zones passing through e (101)—it is in fact rare to find a zone without at least three forms in it, though not necessarily on any single crystal—and the angles between the forms in the same zone almost invariably obey the law of simple anharmonic ratios. After a few crystals had been measured in the manner described above, it was found that all the prominent faces lie in certain zones whose azimuths are approximately: $36\frac{1}{2}°$, $46\frac{1}{2}°$, 56°, $61\frac{1}{2}°$, 75°, 82°, 68°–69°, 90°. Measurements were also made from the pole of intersection of the prism zone with that including the forms $[x, b, b', x']$; but no zonal relations could be found except those which naturally follow from the fact that the pole of reference is tautozonal with x and b, namely: $[\omega, p, P']$; $[x_1, o, y']$, etc. Now in the case of ordinary crystals, which are not twinned, the azimuths of pyramidal forms, when measured from a pole in the prism zone, representing an actual or a possible face, obey the law of simple anharmonic ratios. Such relations were accordingly looked for among the azimuths at e (101) ;

but without success, until it was noticed that the first six do give simple ratios, but only if arranged in the following manner: $36\frac{1}{2}°$, $46\frac{1}{2}°$, $61\frac{1}{2}°$, 82°, 105°, 124°, the last two being the supplements of 75° and 56°; this is tantamount to assuming that the crystals have triclinic symmetry, and are pseudo-monoclinic owing to twinning about an axis parallel to

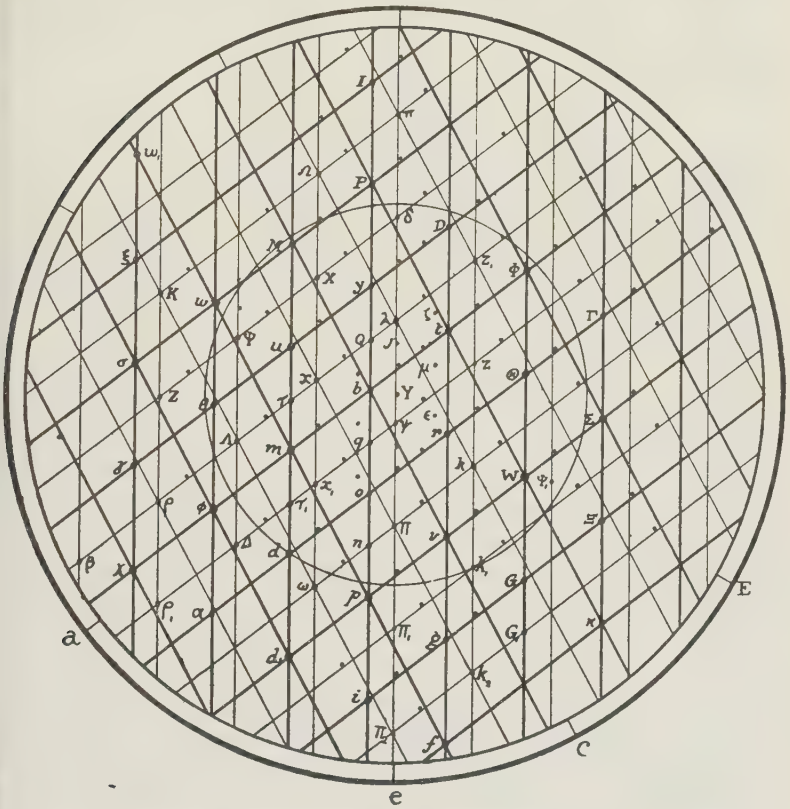

FIG. 3.—Gnomonic projection on a plane perpendicular to the edge of the prism zone (left-handed termination).

the edge of the prism zone. Further investigation revealed the existence of other zones, whose azimuths, 21°, 137°, 146°, also fall in with this arrangement.

The next step was to investigate the existence of cross-zonal relations, and accordingly measurements were made from the pole of intersection of the prism zone with the zone containing the forms $[m, b, t]$, at which a face, a (100), was frequently observed. Here again certain zones were

TABLE III.—Measurements from a (100).

Form.		Calculated Values.				Observed Means.				Edges.	Limits of Observations.							
		Azimuth.		Distance.		Azimuth.		Distance.			Azimuth.				Distance.			
		°	′	°	′	°	′	°	′		°	′	°	′	°	′	°	′
e	101	0	0	52	18½	...		...		...	...	...	...		...	...	...	
p	111	53	1½	58	50	53	1	58	56½	14	52	28	53	20	58	43	59	22
v	011	,,	,,	78	52	,,	,,	78	48	3	,,	,,	,,		78	42	78	56
W	$\bar{1}11$	,,	,,	101	55	,,	,,	101	49	3	,,	,,	,,		101	48	101	50
F	$\bar{1}7.4.3$	61	42½	149	56½	61	54	150	37	1	...	...	...		...	...	...	
d	321	72	4½	48	19	72	4	48	23	3	71	32	72	26	48	9	48	30
o	121	,,	,,	67	58½	,,	,,	68	2½	14	,,	,,	,,		67	51	68	15
r	$\bar{1}21$	,,	,,	94	38½	,,	,,	94	38	6	,,	,,	,,		94	35	94	39
q	141	83	47	75	32½	83	41	75	36½	16	83	10	83	59	75	26	75	50
μ	$\bar{1}7.24.3$	89	54½	103	59	90	0	104	20½	7	89	55	90	7	104	12	104	34
ϕ	210	96	2	42	3	95	54½	42	1½	6	95	0	96	18	41	48	42	10
m	110	,,	,,	59	0	,,	,,	59	2½	22	,,	,,	,,		58	34	59	25
b	010	,,	,,	84	41	,,	,,	84	40½	18	,,	,,	,,		84	25	84	50
t	$\bar{1}10$	,,	,,	112	31½	,,	,,	112	29	8	,,	,,	,,		112	14	112	48
Φ	$\bar{2}10$	,,	,,	132	41½	,,	,,	132	32	3	,,	,,	,,		132	29	132	45
x	$\bar{9}.20.\bar{5}$	107	46	74	48½	107	45½	74	54	9	107	37	107	57	74	30	75	7
θ	$32\bar{1}$	118	9	55	24	118	7	55	23	3	117	45	118	24	55	20	55	30
u	$12\bar{1}$	,,	,,	76	29½	,,	,,	76	29½	12	,,	,,	,,		76	12	76	40
y	$\bar{1}2\bar{1}$	,,	,,	101	51½	,,	,,	101	51½	7	,,	,,	,,		101	42	101	59
D	$\bar{3}2\bar{1}$	,,	,,	123	25½	,,	,,	123	16	2	,,	,,	,,		123	11	123	21
w	$11\bar{1}$	133	57½	72	0	133	57½	71	49½	14	133	49	134	12	71	9	72	6
M	$01\bar{1}$	,,	,,	92	26½	,,	,,	92	25½	7	,,	,,	,,		92	6	92	45
P	$\bar{1}1\bar{1}$	,,	,,	112	18½	,,	,,	112	14	3	,,	,,	,,		112	4	112	21
w_1	$11\bar{2}$	151	15	81	49½	151	5	81	29	1	...	...	...		...	...	...	

The faces F and w_1 were observed only on a skeletal crystal, and owing to the peculiar shape of the crystal no measurements could be made of these faces from e (101).

encountered which obey the same law, but only if arranged in the following manner: 53°, 72°, 84°, 96°, 118°, 134°. Measurements from this pole are given in Table III (p. 138), but only those of the more prominent forms made on fourteen crystals are included.

The zones of one individual very nearly coincide with those of the twin individual. For instance, the face q (141) of one lies very nearly in the zone $[m, b, t]$ of the other; in fact, on many crystals the agreement is so close that the slight difference may be due to error of adjustment; but, as a reference to the table will show, there is on the whole a small difference in the azimuths, amounting in the mean values to 24′.

Measurements were further taken from the intersection of the prism zone with the prominent zone containing the forms $[f, p, m, w]$; this pole is c (001) whichever class of symmetry be chosen, and frequently represents an actual face. Here again the azimuths satisfy the law of simple anharmonic ratios, but only if arranged in the following manner: $58\frac{1}{2}°$, 70°, 77°, 98°, $111\frac{1}{2}°$. Measurements from this pole are given in Table IV (p. 140), but only those of the more prominent forms made on thirteen crystals are included.

The concordance between the calculated and the mean observed values of the coordinates of the faces passing through the nodes of the principal lattice is so close that we can scarcely regard the agreement as accidental, and we must conclude that this lattice has a real existence in calaverite.

There are many forms which clearly from the complexity of their indices do not harmonize with the principal lattice: the most prominent of these are x (9·20·$\bar{5}$), ω (29·20·15), k ($\bar{1}\bar{1}$·20·15), z ($\bar{2}\bar{1}$·20·5), Π (9·20·15), Λ (29·20·$\bar{5}$), Ψ (19·20·$\bar{1}5$), ρ (49·20·$\bar{5}$). The indices, though complex, indicate that the faces are in harmony with a second lattice. The symbols which they receive on this hypothesis are given in another column of Table I. The prism zone is common to the two lattices, and the zones at a (100) are very nearly, if not quite, coincident. The positions of the forms of this group vary considerably. x (9·20·$\bar{5}$), which is the best developed form, on some crystals lies very nearly in the zone $[o, r]$, but on others it lies an appreciable distance away. Again, the azimuth of the zone $[x, x_1, \omega]$ usually exceeds that of the zone $[k, z]$, but on some crystals it is distinctly less.

There still remain the common forms Y ($\bar{5}$·24·3), μ ($\bar{1}\bar{7}$·24·3) and the rarer forms J ($\bar{1}\bar{1}$·24·3), Ψ_1 ($\bar{2}\bar{9}$·24·27), ζ ($\bar{2}3$·24·3), ϵ ($\bar{1}\bar{1}$·24·9), which do not harmonize with either of the above lattices, but do harmonize with a third, a monoclinic, lattice. Here again the prism zone is the same as before.

TABLE IV.

Measurements from *c* (001).

Form.		Calculated Values.		Observed Means.		Edges.	Limits of Observations.	
		Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.
		° ′	° ′	° ′	° ′		° ′ ° ′	° ′ ° ′
e	101	0 0	27 36	...	...	...	... ...	... ...
f	112	58 28½	33 54	58 28½	33 58	5	58 7 – 58 57	33 20 – 34 6
p	111	,, ,,	53 19	,, ,,	53 21	17	,, ,, ,,	53 7 – 53 36
m	110	,, ,,	89 55	,, ,,	89 58½	12	,, ,, ,,	89 45 – 90 19
w	11$\bar{1}$	,, ,,	126 34	,, ,,	126 33½	10	,, ,, ,,	126 13 – 126 46
o	121	70 6	69 43	70 5½	69 43½	14	69 55 – 70 20	69 25 – 70 1
u	12$\bar{1}$	,, ,,	114 14½	,, ,,	114 16	5	,, ,, ,,	114 10 – 114 20
x	9·20·5	71 23	104 7	71 27	104 15	3	71 17 – 71 40	104 12 – 104 19
q	141	76 42	81 33	76 48	81 27½	7	76 40 – 77 5	81 10 – 81 45
v	011	83 41	52 3½	83 40	52 14	3	83 25 – 83 59	52 11 – 52 17
b	010	,, ,,	94 59	,, ,,	95 0	6	,, ,, ,,	84 52 – 85 25
M	01$\bar{1}$	,, ,,	133 39	,, ,,	133 43	3	,, ,, ,,	133 40 – 133 45
r	$\bar{1}$21	98 0½	73 16	97 57	73 20	6	97 45 – 98 10	72 41 – 73 30
y	$\bar{1}$2$\bar{1}$	,, ,,	119 23	,, ,,	119 25½	3	,, ,, ,,	119 6 – 119 30
k	$\bar{1}\bar{1}$·20·15	99 25	62 58	99 38	63 3	4	99 10 – 100 0	62 9 – 63 38
W	$\bar{1}$11	111 24½	57 6	111 16½	57 15	2	111 7 – 111 30	57 15
t	$\bar{1}$10	,, ,,	99 22	,, ,,	99 20	5	,, ,, ,,	99 16 – 99 38

We are, therefore, driven to the remarkable conclusion that five distinct lattices may be traced in calaverite, which are incongruent but not independent. The prism zone is common to all. The faces [*x*, *b*, *Y*, *b*′, *x*′] which lie on the different lattices are tautozonal; a fact which does not immediately follow from the symbols assigned to forms *x* and *Y*, namely (9·20·5) and (5·24·3) respectively, but these have merely been selected because they are the simplest which accord with the observations. There seems, indeed, from direct observation with the goniometer, no doubt that the faces in question do lie in a zone, and further we have tan *Yx* = 3 tan *Yb*, because this equation is satisfied by their azimuthal angles; for tan 82° 6½′ = 3 tan 67° 25′, which agrees closely with the mean observed azimuth of *x*, namely, 67° 29½′. The zones of the different

lattices passing through $a(100)$ apparently coincide. Such is not the case at c (001); nevertheless there is a relation, as is clear from a study of the first two indices of the various forms, e.g.:—z (21·20·5), k ($\bar{1}\bar{1}$·20·15), x (9·20·5), Ψ (19·20·$\bar{1}\bar{5}$), ω (29·20·15), etc., and μ ($\bar{1}\bar{7}$·24·3), J ($\bar{1}\bar{1}$·24·3), Y (5·24·3), etc.; there is a regular decrement in the first very simply related to the second symbol. This relation is very clearly shown on the gnomonic projection; for, in consequence, the linear distances of points lying on parallel lines are multiples of the same unit. These several relations involve other tautozonal relations connecting poles on different lattices, such as: $[\rho, m, b', \Lambda']$, $[w', \Psi_1, W, k]$, $[Y, m, \beta]$, etc., in all of which the law of simple anharmonic ratios is obeyed. Finally, the two individuals of the two pairs of triclinic lattices are connected by twinning about Y or, what comes to the same thing, the edge of the prism zone.

The question now arises, what explanation can be offered of the unique anomalies presented by calaverite? On the one hand, we have a morphological development of the faces which is completely in accord with monoclinic symmetry. This view of the symmetry is confirmed by the frequent occurrence of a face of the form Y, which invariably gives a single distinct image, and not one blurred or double, such as would be expected did it really belong to two or more separate individuals. The faces also occur in positions similar to those of their poles on the sphere of projection, and there are none of the markings or re-entrant angles (beyond those in the prism zone) which usually accompany twinning, however much concealed. Later on, when we proceed to consider twin crystals, we shall find that the planes of twinning except that of the fourth, a doubtful type, have simpler indices on the hypothesis of monoclinic symmetry.

Yet, on the other hand, how can we be satisfied with an interpretation which necessitates the assigning of such complex symbols to even the commonest and best developed forms? The fundamental constants possess no meaning beyond the concise representation of the lattice of the space-partitioning. The crystal faces pass through the nodes of such a lattice, and the commonest faces are those in which the nodes are most crowded. Faces of this kind have simple indices; faces with complex symbols are usually due to corrosion. Although corrosion frequently does produce bright plane faces having high indices, we can scarcely regard all the faces of these crystals to be the result of corrosion.

Owing to the opacity of the crystals no optical test is possible, and, even if it were, it would not be infallible, since we know that if a crystal

be composed of several overlapping individuals the resulting optical phenomena are precisely those of the symmetry simulated. Etching tests are more searching, but were in this case without result. A plane ground approximately perpendicular to the edge of the prism zone was etched with nitric acid and with aqua regia; the former produced numerous fine markings roughly in the same direction, and the latter merely a ripple effect.

A comparison of calaverite with the other gold tellurides, sylvanite and krennerite, does not throw much light on the problem, except for the interesting fact that the principal zone $[e, p, o, q, b]$ of calaverite is similar to one zone of sylvanite and two zones of krennerite.

TABLE V.

Calaverite. Distance from 101.		Sylvanite[1]. Distance from 101.		Krennerite[1]. Distance from 100.			
° ′		° ′		° ′		° ′	
$\bar{3}23$	32 14	323	31 38½	301	31 52	320	32 5½
323	31 24						
$\bar{1}11$	43 38½	111	42 45	201	43 0	110	43 15
111	42 15						
$\bar{1}21$	62 55½	121	61 35	101	61 48	120	62 0½
121	60 36						
$\bar{1}41$	76 22	141	74 56	102	74 59½		
141	73 34						
010	91 30	010	90 0	001	90 0	010	90 0
0$\bar{1}$0	88 30						

The zone $[c\ p\ m]$ also has a counterpart in sylvanite.

TABLE VI.

Calaverite.			Sylvanite[1].		
	Azimuth.	Distance.		Azimuth.	Distance.
	° ′	° ′		° ′	° ′
111	58 28½	53 19	111	58 32	52 44
110	„ „	89 55	110	„ „	89 47

It is owing to this similarity that constants so nearly equal to those of sylvanite are obtained from calaverite on the hypothesis of monoclinic symmetry, and with the orientation of Penfield and Ford. If, indeed, we imagine the zone $[c, p, m]$ kept fixed, and the remaining zones moved in such a way that b is brought into coincidence with Y, we obtain very nearly the constants and angles of sylvanite.

[1] The values are taken from Dana's 'System of Mineralogy,' 6th edition, 1892.

Calaverite differs from sylvanite and krennerite in displaying no cleavage, although it is extremely brittle. If calaverite be really isomorphous with sylvanite, as is suggested by certain characters—the similarity of certain angles and zones, and the twinning about a similar face (type 1)—we should expect from analogy with the felspars, that even if they belong to different systems of symmetry both would display similar cleavage; but this is not the case. The brittleness of calaverite indicates that there is a facility of parting which is not in the same direction at every point. If the crystals are composed of two or more individuals so intimately intermixed that the separation is not visible to our perceptions, and if each individual has a cleavage in corresponding but not parallel directions, the brittleness would be explained: and further, if the constituent individuals at particular points are sufficiently small, the fractured surfaces would not give distinct and definite reflections; the surfaces in fact give a blur of light.

In the present state of our knowledge we can do little more than conjecture what may be the actual arrangement of the ultimate parts in any particular mineral, although we are agreed that it must belong to one of 230 different classes. The case of calaverite is one of peculiar perplexity. Professor W. S. Myers[1] has found that the composition of krennerite from the Cripple Creek District is essentially the same as that of calaverite; but the former crystallizes in the orthorhombic system and presents no anomalies. Whatever meaning may be attached to the three or, including the corresponding twins, five lattices apparently existing in calaverite, it is obvious that if they coexisted at every or, indeed, any point of the crystal, heterogeneity would be the necessary consequence of their incongruence. The only hypothesis remaining appears to be the existence of a minute skeletal structure of some kind—an infinitesimal framework composed of material with an arrangement according to one lattice intercalated with material with an arrangement according to another lattice. Since the lattices, while not congruent with one another, have a zone in common, i.e. the rows parallel to its edge equidistant, or at least congruent, in parallel planes, and have other relations, discussed above (pp. 140–1), interaction at some of the boundaries separating the differently constituted sections would seem to be indicated. This hypothesis is in harmony with the suggestion made above as to the origin of the brittleness of crystals. The frequent occurrence of pits on the faces, and the existence of skeletal and hollow crystals, suggest breaks in continuity of the homogeneous arrangement.

[1] Amer. Journ. Sci., 1898, ser. 4, vol. v, p. 376.

As the facts require the parts of the hypothetical structure to be referable to three or more distinct structures, calaverite would then be in no way similar to such a substance as leucite, which exhibits optical anomalies. The optical investigation of such a substance shows that there is a clear and definite separation between the individuals which build up the crystal; on calaverite the faces occur just as they would if the crystal were composed of a single homogeneous individual.

Such are a few of the speculations that arise, but an adequate explanation is not forthcoming. Perhaps similar zonal relations may be found to exist in other minerals, and increased knowledge may furnish a clue which will ultimately lead to the elucidation of the mysterious symmetry of a most remarkable mineral.

Twin Crystals.

Whatever may be the explanation of the remarkable symmetry presented by calaverite, the crystals are susceptible of twinning in the usual manner about certain faces. Three types of twinning have been established, and to these possibly a fourth may be added.

Type 1. *Plane of twinning*: e_1 (705) T_1, (101) **M**.

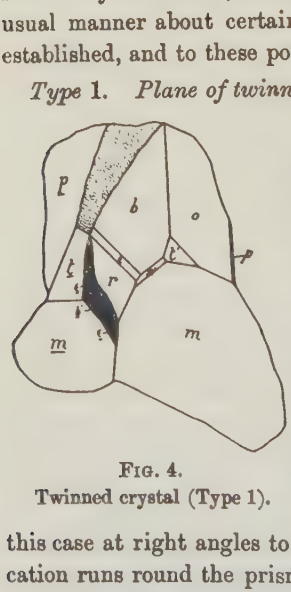

Fig. 4.
Twinned crystal (Type 1).

This, a very common type of twinning, has already been described by Penfield and Ford[1]. The twin striae mentioned by these authors were not noticed on any of the crystals measured, eleven in number. The plane of composition is usually either parallel or perpendicular to the plane of twinning. Fig. 4 shows the former mode and fig. 6 both; fig. 5 would probably have shown both had the crystal been unbroken. One large crystal possesses faces at the lower end which are in the positions required by this type of twinning, and the plane of composition is in this case at right angles to the edge of the prism zone. A line of demarcation runs round the prism zone, roughly at right angles to its edge.

In this type the faces of the form p (111) of the two individuals composing the twin are parallel, and the plane through the poles of these faces and the edge of the prism zone becomes one of symmetry. The crystals were measured in the usual manner, and one adjustment of the crystal is sufficient, since the direction of the edge of the prism zone

[1] Loc. cit., p. 237.

is the same in the two individuals. The difference in the readings of the circle C, when each individual is in the position to be measured from a face of the form e (101) as pole of reference, gives at once the distance between the two positions of these faces. The mean of eight observed values, ranging from 14° 50′–15° 35′, is 15° 13′; the value calculated from the azimuth and distance of p (111), given in Table I, is 14° 56′, the half of which is 7° 28′. The calculated distance of e_1 (705) from e (101) is 7° 36½′. The plane of twinning might, of course, be in the prism zone distant a quarter of a revolution from e_1 (705), i. e. at a distance from e (101) of 82° 32′, the complement of 7° 28′. The nearest pole with simple indices is E_6 ($\bar{2}01$), the distance of which is 83° 1½′.

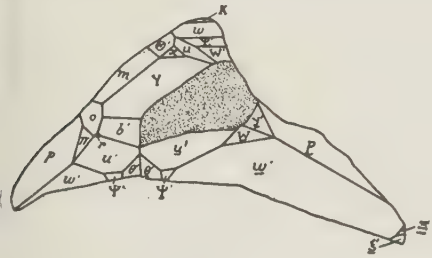

FIG. 5.

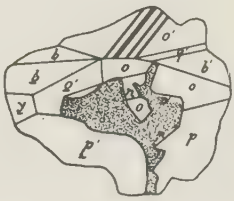

FIG. 6.

Twinned crystals (Type 1).

Some of the twins have a number of such minute faces on the boundary between the two individuals that considerable difficulty was experienced in determining to which of the two any particular face belonged. It may be remarked that, when the plane of composition is parallel or at right angles to the plane of twinning, the ends of the two individuals which compose the termination of the twin crystal are of opposite hands.

Type 2. *Plane of twinning*: p (111).

Penfield and Ford refer to this type, but the material at their disposal was not sufficiently good for the determination of the law of twinning. Fig. 7 represents an actual twin of this kind. The small portion to be noticed projecting from one individual is in the position required by the law of type 3. The other individual is remarkable for possessing both terminations. The angle in the prism zones towards the observer is re-entrant. The terminations of the crystals observed, four in number, have comparatively few faces.

These and other cross twins are easily measured on the three-circle

goniometer. The prism edge of one individual is adjusted parallel to the axis of the circle *C*. The angle of crossing of the prism zones of the two individuals is at once determined, and measurements of the terminal faces of both may be made from the pole of intersection of the two zones. The individual, whose prism edge is in adjustment, may be measured in the usual way from the pole *e* (101). The second individual may then be adjusted and measured in a similar manner. The plane of twinning is now readily found. Measured from the pole of crossing, its distance is 90° and azimuth either half the acute angle or half the obtuse angle of crossing. Both will probably not give possible poles, but any doubt is removed by a consideration of the positions of the terminal forms of both individuals measured from the pole of crossing.

The plane of twinning does not seem to quite coincide with *p* (111). On the crystal figured the zone [*e*, *p*, *o*, *b*] is well developed on both individuals, and the two were found not to be in coincidence, as they should be. The mean value of the angle of crossing measured on the four crystals, ranging from 86° 33′–86° 54′, is 86° 41′; the calculated value is 86° 15′. The mean of four values of the distance of the pole of crossing from *e* (101), ranging from 82° 4′–82° 17′, is 82° 10′; the calculated value is 82° 32′.

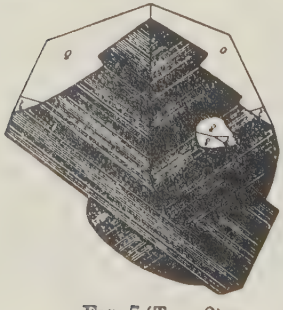

FIG. 7 (Type 2).

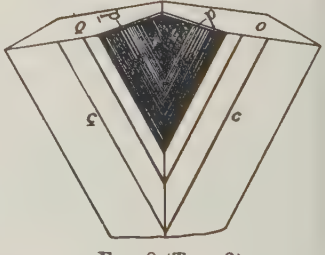

FIG. 8 (Type 3).

Twinned crystals.

Type 3. *Plane of twinning*: β (69·20·5) T_1, (310) T_2, (310) **M**.

In this type the prism zones cross at a much smaller angle (fig. 8). As in the previous type the terminations have comparatively few faces. Altogether six twins were observed, including that shown in fig. 7. They were measured in a similar manner to those of the preceding type. The mean of five values of the angle of crossing, ranging from 56° 29′–57° 38′, is 57° 5′; the calculated value is 56° 55′. No reliable measurements of the distance of the pole of crossing from *e* (101) were obtainable, owing to the insufficient development of the

principal zone [*e*, *p*, *o*, *b*]. Four values were observed; 27° 43′, 28° 16′, 28° 47′, 29° 24′, the mean of which is 28° 37′; the calculated value is 27° 42′. The zones, therefore, cross very nearly in the pole *c* (001), the calculated distance of which from *e* (101) is 27° 36′. The faces of this form, belonging to the two individuals, seem to be coincident on the crystal figured.

One of the observed crystals is composed of three individuals, the middle one having an individual on each side in the positions required by twinning about the faces β and β'.

There are two crystals which call for special remark. At first sight they appear to be twins of type 3, and the angle of crossing is, indeed, the same; but on measuring one crystal, which is much better developed than the other, from the pole of crossing of the two prism zones it was found that the distances of the most prominent faces, evidently belonging to the form *o* (121), are not the same on the two individuals; on one the measurements were 69° 45′ and 69° 40′, and on the other 65° 19′ and 65° 31′. From further investigation it appeared that we have here a combination of the laws of types 1 and 3. Careful search was made for an intermediate individual, but no trace of such could be perceived on either crystal. The zone [*e*, *p*, *o*, *b*] is sufficiently well developed on one to furnish a fairly accurate setting for *e* (101), and the distance from this pole to the pole of crossing of the prism zones can be measured; it was found to be 41° 59′: the calculated value is the sum of 14° 56′ and 27° 42′, or 42° 38′. The calculated values of the distance of the faces of the form *o* (121) on the two individuals from the pole of crossing are 70° 6′ and 65° 17′, which are in fairly close agreement with the observed values given above.

Type 4. *Plane of twinning* (?): K_1 (19·20·35) T_1, (123) T_2.

The existence of this type requires further confirmation. Only one such crystal (fig. 9) has been observed, and that was encountered at the close of the investigation. Were it not for the occurrence of the crystals just described it would have been assumed to be a fortuitous conjunction of two distinct crystals. Each individual is capable of being measured with considerable accuracy, and each in turn was adjusted with its prism edge parallel to the axis of the circle *C*. The pole of crossing is not at the same distance from *e* (101) in the two cases; on the individual whose

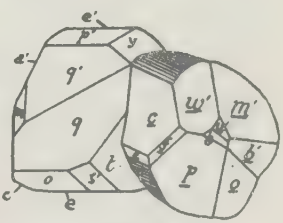

FIG. 9.
Twinned crystal (Type 4).

prism edge is perpendicular to the plane of the paper in fig. 9, the distance measured is 25° 54′; on the other an accurate reading was not obtainable, but it is approximately 40° 35′. The difference between the two measurements is very suggestive, because it is very nearly that demanded by the law of type 1 as the angle between the two positions of *e* (101). We may, therefore, have again a combination of two laws, one belonging to type 1 and the other to a type to be determined. The observed angle of crossing is 60° 27′. The plane of twinning which satisfies the conditions best is K_1 (19·20·$\bar{35}$) T_1, (12$\bar{3}$) T_2, a form which has not yet been observed. The calculated value for the angle of crossing is 62° 49′, and that of the distances of the pole of crossing from *e* (101) on the two individuals is 41° 21′ and (less 14° 56′) 26° 25′. The agreement, therefore, between the calculated and observed values is not sufficiently close to prove the certain existence of this type of twinning.

Pseudomorphs.

The British Museum collection contains numerous altered crystals both on the matrix and isolated. They are usually prismatic with indications of terminal faces, but twins of types 2 and 3 have been noticed. Some consist apparently of pure gold, and others are merely altered on the surface. The colour is a rusty reddish-yellow or a pale buff-yellow. The alteration is evidently due to the oxidation of the telluride.

Chemical Composition.

Quantitative analyses were made by Mr. G. T. Prior on crystals carefully picked out from specimens from Raven Hill, and also on large isolated crystals without terminal faces, the exact localities of which are not stated on the labels.

The mineral was decomposed by aqua regia, and the small amount of silver chloride separated. In the filtrate the gold was precipitated by means of ferrous sulphate, and the tellurium by means of ammonium sulphite.

Results of analyses:—

	(1) Raven Hill crystals.	(2) Isolated crystals.
Weight of material used	0·5096 gram.	0·4196 gram.
„ Au	0·2123	0·1758
„ AgCl	0·0056	0·0034
„ Te	0·2949	0·2389

	(1)	(2)	Calculated. $AuTe_2$
Au	41·66	41·90	44·03
Ag	0·77	0·79	....
Te	57·87	56·93	55·97
	100·30	99·62	100·00

The material contains, therefore, little silver. The numbers obtained in the analyses agree fairly well with the formula $AuTe_2$.

The following determinations of the specific gravity (i.e. the weight of 1 cc.) were made on isolated crystals, which were broken up into small fragments, but not crushed to powder, before being weighed:—

Weight of material used.	Specific gravity.
0·8131 gram.	9·163
0·7612	9·148
0·4259	9·153
	Mean value 9·155

The numbers here given agree closely with the determinations of Genth and Hillebrand; all are appreciably lower than the numbers given by Penfield[1], namely, 9·328 and 9·388.

Summary.

The following are the main points discussed in this paper:—

Judged merely from its morphological development, calaverite appears to crystallize in the monoclinic system, the axis of symmetry being parallel to the edge of the prism zone; but the indices which must be assigned to the faces on this hypothesis are exceedingly complex. The faces are, however, found to lie in zones, but these cannot be referred to a single space-lattice: in fact there appear to be in all five distinct lattices which are incongruent, but not independent; the relations between them are discussed above (pp. 140–1). Since the morphological development of the crystals cannot be referred to one lattice, calaverite cannot resemble in structure those transparent substances which display the so-called optical anomalies. The actual co-existence of two or more incongruent lattices would result in heterogeneity, and the only plausible hypothesis, by which we may explain the strange phenomena displayed by this mineral, seems to be that there is a close intermixture

[1] Loc. cit., p. 246.

throughout the structure of arrangements corresponding to different lattices.

Four types of twin crystals are described, of which the fourth depends on a single crystal, and requires confirmation. In the case of two remarkable twins one individual may be derived from the other by means of successive half-turns about the twin axes of types 1 and 2; no trace of an intermediate individual is discernible. The crystal representing type 4 may be another instance of this double twinning.

The crystals contain little silver, and in chemical composition approximate to the formula $AuTe_2$.

Sulpharsenites of Lead from the Binnenthal [1].

Part III.—Baumhauerite, a new mineral; and Dufrenoysite.

By R. H. Solly, M.A.
With an analysis by H. Jackson, M.A.

[Read November 12, 1901.]

Baumhauerite [2], $4PbS.3As_2S_3$.

FOR this new mineral I propose the name baumhauerite in honour of Dr. H. Baumhauer, Professor of Mineralogy in the University of Freiburg, Switzerland, who has done so much to elucidate this complicated group of sulpharsenites of lead.

Crystallography.

System: Oblique. $a : b : c = 1{\cdot}136817 : 1 : 0{\cdot}947163$; $\beta = 82°42\frac{3}{4}'$.

These elements are calculated from the angles $100 : 101 = 50°27'$, $101 : 001 = 32°15\frac{3}{4}'$ and $010 : 11\bar{1} = 50°33'$ measured on crystal No. I.

The crystals closely resemble dufrenoysite and jordanite in appearance. They may be distinguished from dufrenoysite by the marked oblique development of the zone [100,001], and from jordanite by the absence of twin striations and by the colour of the streak. The edges in the pyramid zone and between planes in the zone [100,010] are more or less rounded. The orthopinacoid (100), which is the direction of cleavage, is always largely developed and has a brilliant lustre; it is sometimes finely striated parallel to the axis of symmetry, and sometimes shows unsymmetrical markings. The best developed zone on the crystals is [100,001]. The prism zone [100,010] is sometimes deeply furrowed as in rathite and dufrenoysite. Sometimes similar planes on opposite sides of (010) give different angles; this may possibly be due to twinning about a plane making a small angle with (100),

[1] Part I.—General Description and Chemical Analyses, with a Crystallographic account of Jordanite. This Magazine, 1900, vol. xii, pp. 282–97. Part II.—Rathite. This Magazine, 1901, vol. xiii, pp. 77–85. These two parts have been published together in Zeits. Kryst. Min., 1901, vol. xxxv, pp. 321–44.

[2] A preliminary notice of this new mineral was published in 'Nature,' Oct. 10, 1901, vol. lxiv, p. 577, but no name was then given to it.

as has been observed on rathite and dufrenoysite. The pyramid planes are fairly numerous but small. Table I given below contains the list of ninety-five forms which have been observed on the crystals. The positions of most of these forms are indicated on the stereographic projection (fig. 1).

There are four habits to be distinguished:—

I. Characterized by the large development of (010) (fig. 2).

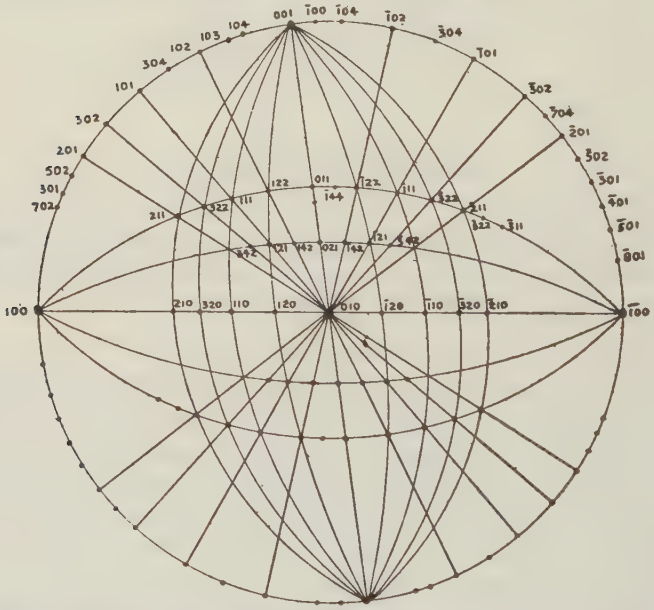

Fig. 1.—Stereographic projection of baumhauerite, showing most of the observed forms.

II. Plate-like crystals with (100) large, somewhat resembling jordanite in shape (fig. 3).

III. Rhombic prisms with small terminations, resembling habit I of dufrenoysite (p. 164).

IV. Simple rhombic-shaped crystals resembling Berendes' drawing of dufrenoysite.

The colour of baumhauerite is lead-grey to steel-grey, sometimes tarnished with iridescent colours. The lustre is metallic and brilliant. The streak chocolate colour. The mineral is opaque. There is a very perfect cleavage parallel to the orthopinacoid (100). Fracture conchoidal. Hardness 3. Specific gravity 5·330.

Baumhauerite occurs, usually as isolated crystals, with the other sulpharsenites of lead in the white crystalline dolomite in the bed of the Lengenbach, Binnenthal; this is the only locality known for the mineral.

Two crystals have been examined by Prof. Baumhauer and his results are given below. My own observations have been made on thirteen crystals, two of which I obtained at Binn in 1898, and the others in August, 1901. There is little doubt that many museums[1] contain specimens of this new mineral under the name of dufrenoysite or jordanite.

TABLE I.—LIST OF FORMS OBSERVED ON BAUMHAUERITE.

Symbol.	Indices.	Symbol.	Indices.	Symbol.	Indices.	Symbol.	Indices.
a	100	$-\frac{5}{8}g$	508	$+\frac{2}{5}g$	$20\bar{5}$	$-2q$	121
b	010	$-\frac{1}{2}g$	102	$+\frac{3}{8}g$	$30\bar{8}$ *B.*	$-p$	111
c	001	$-\frac{2}{5}g$	205	$+\frac{1}{3}g$	$10\bar{3}$ *B.*	$+2q$	$12\bar{1}$
$-30h$	30.0.1	$-\frac{1}{3}g$	103	$+\frac{1}{4}g$	$10\bar{4}$	$+p$	$11\bar{1}$
$-\frac{25}{2}h$	25.0.2	$-\frac{1}{4}g$	104	$+\frac{2}{13}g$	$2.0.\bar{13}$	$+u$	$21\bar{1}$
$-\frac{13}{2}h$	13.0.2	$-\frac{1}{6}g$	106	$+\frac{1}{9}g$	$10\bar{9}$	$-4x$	342
$-5h$	501	$-\frac{1}{7}g$	107	$+\frac{1}{12}g$	$1.0.\bar{12}$	$-2x$	322
$-\frac{9}{2}h$	902	$-\frac{1}{9}g$	109			$+2x$	$32\bar{2}$
$-4h$	401	$+8h$	$80\bar{1}$	$4r$	140	$-4n$	142
$-\frac{7}{2}h$	702	$+\frac{11}{2}h$	$11.0.\bar{2}$	$2r$	120	$-2n$	122
$-3h$	301	$+5h$	$50\bar{1}$	$\frac{4}{3}r$	340	$+4n$	$14\bar{2}$
$-\frac{13}{5}h$	13.0.5	$+4h$	$40\bar{1}$	r	110	$+2n$	$12\bar{2}$
$-\frac{5}{2}h$	502	$+3h$	$30\bar{1}$	$\frac{2}{3}s$	980	$-2y$	522
$-\frac{13}{6}h$	13.0.6	$+\frac{5}{2}h$	$50\bar{2}$	$\frac{3}{2}s$	320	$+2y$	$52\bar{2}$
$-2h$	201	$+\frac{11}{5}h$	$11.0.\bar{5}$	$\frac{2}{5}s$	950	$+z$	$31\bar{1}$
$-\frac{13}{7}h$	13.0.7	$+2h$	$20\bar{1}$	$2s$	210	$-w$	411
$-\frac{3}{2}h$	302	$+\frac{13}{7}h$	13.0.7	$\frac{17}{8}s$	17.8.0	$-3W$	10.3.3
$-\frac{7}{5}h$	705	$+\frac{7}{4}h$	$70\bar{4}$	$\frac{5}{2}s$	520	$-3V$	16.3.3
$-\frac{4}{3}h$	403	$+\frac{5}{3}h$	$50\bar{3}$ *B.*	$\frac{8}{3}s$	830	$+4m$	$14\bar{4}$
$-\frac{7}{6}h$	706 *B.*	$+\frac{8}{5}h$	$80\bar{5}$ *B.*	$3s$	310	$-10T'$	4.10.5
$-\frac{13}{12}h$	13.0.12	$+\frac{3}{2}h$	$30\bar{2}$	$\frac{10}{3}s$	10.3.0		
$-h$	101	$+h$	$10\bar{1}$	$\frac{11}{3}s$	11.3.0	k	011
$-\frac{5}{6}g$	506	$+\frac{3}{4}g$	$30\bar{4}$	$\frac{11}{2}s$	11.2.0	$2k$	021
$-\frac{4}{5}g$	405	$+\frac{2}{3}g$	$20\bar{3}$			$\frac{1}{2}l$	012
$-\frac{3}{4}g$	304	$+\frac{1}{2}g$	$10\bar{2}$				

B. refers to the planes observed only by Baumhauer.

[1] Measurement of a crystal which had been labelled as dufrenoysite in the British Museum gave angles agreeing with those of baumhauerite.—L. J. S.

TABLE II.—CALCULATED AND MEASURED ANGLES OF BAUMHAUERITE.

	Calculated.	Measured (Solly).							Measured (Baumhauer).			
		Crystal I.	Crystal II (1).	Crystal II (2).	Crystal III.	Crystal IV (1).	Crystal IV (2).	Crystal V.	Crystal 1.	Crystal 2.		
										Fragment (1).	Fragment (2).	Fragment (3).
Zone [100,001]												
100 : 30.0.1	2°43′					2°40						
: 25.0.2	6 27					6 27						
: 13.0.2	12 6					12 0						
: 501	15 27				15°30′							
: 902	17 0½				17 0		16°50′					
: 401	18 54½						18 40	19° 0′				
: 702	21 15½		21°15′			21 16	21	21 14	21°20′*a*			
: 301	24 14		24 14	24°15′	24 14	24 14	24 12	24 12			24°16½′	24°17′
: 13.0.5	27 14	27°10′	27 14	27 15	27 14							
: 502	28 6	28 6				28 6	28 5	28 7	28 6	28°11½′	27 56 28 0½	28
: 13.0.6	31 22	31 6 31 55			31 20							
: 201	33 16½	33 16	33 16		33 16	33 17	33 16		33 20½	33 19½	33 14½ 33 15	33 15½
: 13.0.7	35 5		35 5									
: 302	40 24½		40 24	40 22	40 24	40 25			40 22½*a* 40 23½	40 27½	40 17	40 15 *a*
: 705	42 9	41 21½										
: 403	43 22		43 22									
: 706	46 49								46 45½ *a*			
: 13.0.12	48 31½		48 30			48 32						
: 101	50 27	50 27	50 27	50 27	50 27	50 27	50 26		50 27 50 27	50 27½	50 25	50 23 *b*
: 506	54 39	54 40			54 42							
: 405	55 32				55 30							

	: 301	56 55½			56 55							
	: 303	59 54½	60 35		60 34						59 14½ *b*	
	: 102	64 30½	64 30		64 30	64 30	64 50		64 35 64 35	64 27½	64 29½ 64 32	64 29 64 30½
	: 205	67 53	67 50								67 17	
	: 103	70 10½			70 10	70 12			70 23			
	: 104	73 10½	73 9		73 10½				73 22½	73 9½ *a*	73 5	73 12 *a*
	: 106	76 16½	76 16		76 16	76 25					75 46 *b*	
	: 107	77 10			77 12							
	: 109	78 23½			78 23						79 27 *b*	
	: 001	82 42¾	82 43		82 43		82 45		83 6½ *b*		82 40	82 32½ *b* 82 42
100	: 80$\bar{1}$	10 23		10 10		10 24						
	:11.0.$\bar{2}$	15 5						15 0				
	: 50$\bar{1}$	16 34		16 34	16 34							
	: 40$\bar{1}$	20 34½		20 33		20 34		20 34				
	: 30$\bar{1}$	26 58	26 58	26 57	26 50	26 58	26 58	26 51	27 0	27 0 26 52½		27 4	26 59½
	: 50$\bar{2}$	31 44	31 44	31 44½	31 45	31 44	31 44	31 50	31 45	31 38 31 44½	31 44	31 54	31 48½
	:11.0.$\bar{5}$	35 23½		35 24								
	: 20$\bar{1}$	38 16	38 16	38 15½	38 12	38 16	38 16	38 14		38 21½ 38 29	38 2½	38 12½	
	:13.0.7	39 5		39 8									
	: 70$\bar{4}$	42 27	42 26½	42 27	42 30	42 27	42 27			42 25 42 33		42 31½	42 29½
	: 50$\bar{3}$	44 0								44 3½			
	: 80$\bar{5}$	45 19½								45 16			
	: 30$\bar{2}$	47 25	47 25	47 25			47 25	47 20		47 22½ 47 27½		47 24	47 25
	: 10$\bar{1}$	60 19	60 19	60 19		60 19	60 19	60 20		60 13½ 60 31½		60 20	60 24½ 60 25
	: 30$\bar{4}$	68 25				68 23	68 25						
	: 20$\bar{3}$	71 21½					71 21			71 8			
	: 10$\bar{2}$	77 32			77 30	77 34	77 32	77 31		77 31½ 77 32		77 33 *a* 77 34	77 48½ *a*

a = only fairly good; *b* = bad.

	Calculated.	Measured (Solly).							Measured (Baumhauer).			
		Crystal I.	Crystal II (1).	Crystal II (2).	Crystal III.	Crystal IV (1).	Crystal IV (2).	Crystal V.	Crystal 1.	Crystal 2.		
										Fragment (1).	Fragment (2).	Fragment (3).
: 205	81°22′				81°30′							
Zone [100,001]												
100 : 308	82 22½								82°20′			
: 103	84 1										84°7½′ *b*	84°6′ *b*
: 104	87 20	87°29′	87°20′	87°18′	87 20	87°20′	87°18′		{ 87 12½ / 87 17¼ }	87°18′		
: 2.0.$\bar{1}$3	90 3½	{ 89 24 / 90 40 }			{ 90 20 / 90 40 }	{ 90 15 / 90 30 }						
: 109	92 20	92 20					92 50		92 56¾			
: 1.0.$\bar{1}$2	95 12½	95 20			95 12		95 15					
: 001	97 17¼	97 17			97 17	97 18						
Zone [100,010]												
100 : 11.2.0	13 51½			13 55								
: 11.3.0	20 18½			20 20								
: 10.3.0	22 9		22 9									
: 310	24 20½		24 20									
: 830	26 58½	27 0	26 58									
: 520	28 30		28 30						28 27	28 30	28 42	
: 17.8.0	32 34		32 30									
: 210	34 9½	34 9	34 10						34 5	34 4		
: 950	37 1	37 0	37 0									
: 320	42 8	42 7½	42 8	42 7				42 10	41 57	42 11	41 55	
: 980	50 20½			50 18								
: 110	53 37	53 37								53 24	53 24½	
: 340	61 4½	61 4										
: 120	69 46½	69 46½						69 46		69 46¾		
: 140	79 34	79 32										
: 010	90 0	90 0								{ 90 0½ / 90 13 }	89 55	

a = only fairly good; *b* = bad.

TABLE II (*continued*).

CALCULATED AND MEASURED ANGLES OF BAUMHAUERITE.

	Calculated.	Measured (Solly.) I.	II (2)	IV.	V.		Calculated.	Meas. I.
	° ′	° ′	° ′	° ′	° ′		° ′	° ′
Zone [100,011].						Zone [010,10$\bar{1}$].		
100 : 16.3.3	19 39½			19 40		010 : 12$\bar{1}$	31 17	31 20
: 411	25 14½		25 15	25 16		: 11$\bar{1}$	50 33	50 33
: 10.3.3	29 18		29 20			Zone [010,20$\bar{1}$].		
: 522	36 20		36 23			010 : 21$\bar{1}$	59 36½	59 38
: 322	49 32½	49 32	49 33			Zone [010,302].		
: 111	59 3½	59 4	59 4	59 3	59	010 : 342	39 9½	39 12
: 122	70 54½	70 54	70 55	70 56		: 322	58 27	58 27
: 011	84 42	84 40	84 43	85 0		Zone [010,30$\bar{2}$].		
100 : 31$\bar{1}$	35 1½	35 0				010 : 32$\bar{2}$	55 6½	55 7
: 522	40 26	40 20	40 30			Zone [010,102].		
: 21$\bar{1}$	47 22½	47 20	47 22			010 : 142	30 19	30 19
: 32$\bar{2}$	56 17½	56 17	56 17			: 122	49 28	49 29
: 11$\bar{1}$	67 31	67 31	67 31	67 30	67 30	Zone [010,10$\bar{2}$].		
: 12$\bar{2}$	80 53	80 54	80 54	80 55		010 : 14$\bar{2}$	28 23½	28 33
: 14$\bar{4}$	88 4	88 2				: 12$\bar{2}$	47 14	47 14
: 01$\bar{1}$	95 18					: 11$\bar{2}$	76 59	77 0
Zone [100,021].						Zone [001,110].		
100 : 342	61 15½	61 10				001 : 111	46 56	46 56
: 121	68 55	68 50				: 110	85 41	85 41
: 4.10.5	72 14	72 15				: 11$\bar{1}$	128 9½	128 9
: 142	77 27	77 27				Zone [001,320].		
: 021	86 35	86 30				001 : 322	50 56	50 55
100 : 12$\bar{1}$	75 6	75 5				: 320	84 36	84 35
: 14$\bar{2}$	84 6½	84 10				: 32$\bar{2}$	121 55	121 55
: 02$\bar{1}$	93 25					Zone [001,210].		
Zone [010,001].						001 : 210	83 58½	83 59
010 : 021	28 1½	28 3				: 21$\bar{1}$	116 21½	116 20
: 011	46 47	46 49				Zone [001,120].		
: 012	64 50½	64 50				001 : 122	43 47	43 47
Zone [010,101].						: 121	61 28	61 25
010 : 121	34 24	34 30				: 120	87 29	87 29
: 111	53 51½	53 52				: 12$\bar{1}$	124 31	124 30
						: 12$\bar{2}$	132 42½	132 42

DESCRIPTION OF INDIVIDUAL CRYSTALS.

Crystal I (fig. 2). — A small highly modified crystal of habit I. The clinopinacoid (010) and the orthopinacoid (100) are large. There are fifty-four forms developed on this crystal, including numerous pyramid planes; a list with the measured angles is given in Table II.

In the orthodome zone [100,001] at about 90° from (100) there are a number of narrow planes in oscillatory combination, suggesting that the crystal may be repeatedly twinned on (100), but the rest of the zone shows no indication of twinning.

Crystal II (fig. 3).—This is a fine crystal of habit II; it is highly modified and plate-like in form. It broke into pieces on removal from the matrix of dolomite, and part of it was used for the chemical analysis.

The (100) face is large; the planes in the zones [100,010], [100,011] and [100,001] are narrow but well defined and give excellent reflections. The planes in the zone [100,021] were pitted and rough, so only approximate measurements could be obtained. The crystal has a slight iridescent tarnish. Forty-six forms were determined, a list of which together with the measurements appears in Table II under crystal II (1) and (2).

Crystal III.—A small crystal belonging to habit II; it is much modified, with rounded pyramid and dome zones. Thirty-three forms were determined in the zone [100,001] and are recorded in Table II.

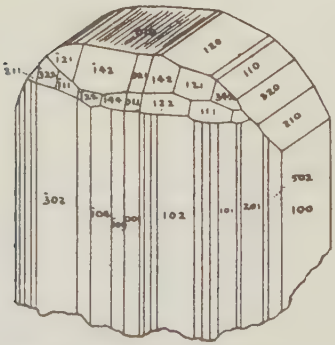

Fig. 2.—Baumhauerite (Habit I).

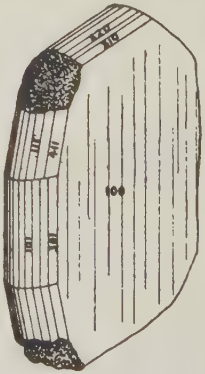

Fig. 3.—Baumhauerite (Habit II).

Crystal IV.—This crystal I found in 1898. I had four similar crystals, but one was used for analysis. They belong to habit II and resemble crystal II by the large development of the (100) face, but most of the planes in the dome and pyramid zone are much rounded. Thirty-three forms were determined in the zone [100,001].

Crystal V. This crystal closely resembles Berendes' figure of dufrenoysite. I obtained it in 1898, and it was not till I removed the crystal from the matrix of dolomite that its difference from dufrenoysite was perceived. The lustre of the upper faces resembles that of ground glass, but that portion of the crystal which rested on the matrix is bright. Fourteen forms were determined and are recorded in Table II.

Crystal VI (fig. 4). This is a very large crystal and measured $22 \times 9 \times 4$ mm. A small portion was broken off and used for analysis.

Fig. 4 is an exact drawing of the crystal. The largely developed faces (100) consist of a number of thin laminae parallel to (100) of decreasing size; the edges are rounded in an unsymmetric manner conformable with the oblique symmetry of this mineral. The crystal is elongated along the axis of symmetry. I had three other very similar crystals, one of which was used for analysis. The following is a list of the forms that were determined on these crystals: (100), (702), (301), (502), (13·0·6), (201), (13·0·7), (302), (705), (403), (13·0·12), (101), (506), (102), (103), (104), (001), (30$\bar{1}$), (50$\bar{2}$), (11·0·$\bar{5}$), (13·0·7), (70$\bar{4}$), (30$\bar{2}$), (10$\bar{1}$), (30$\bar{4}$), (10$\bar{2}$), (10$\bar{4}$), (10$\bar{9}$), (1·0·$\bar{1}$2), (520), (210), (320), (110), (52$\bar{2}$), (21$\bar{1}$), (32$\bar{2}$).

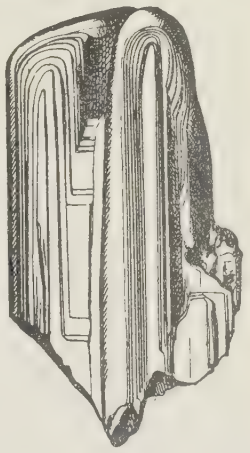

Fig. 4.—Baumhauerite.

Crystals measured by Prof. Baumhauer.

In answer to my letter to Professor Baumhauer, proposing to give his name to this new mineral, he informed me that he had found two crystals of the same mineral in the Freiburg Museum. One of the crystals was detached, and the other was broken into three pieces in freeing it from the matrix. In sending me the results of his measurements, he asked that they might be included in the present paper. On reference to the above Table II, where these are given, it will be noticed that many of his angles are in close agreement with those obtained by myself: for example, the measured values for (100):(101) and (100):(10$\bar{2}$) are identical. In the prism zone [100,010] his measurements are, however, not in quite such close agreement and vary amongst themselves. The dislocation of the planes in this zone I have pointed out on p. 151.

The forms {706}, {50$\bar{3}$}, {80$\bar{5}$}, {30$\bar{8}$} and {10$\bar{3}$}, noted by Baumhauer, are not present on my crystals; on the other hand, he finds no definite pyramid planes such as are especially well developed on many of my crystals.

Chemical Analysis.

The following is Jackson's account of his analysis made on portions of crystals II, IV, and VI.

The mineral was examined and analysed as described in a former

communication (this Magazine, 1900, vol. xii, p. 289). One quantitative analysis only was made, which gave the following results:—

Weight of mineral taken	=	·7785 gram.
„ $PbCl_2$	=	·5108 „
„ $BaSO_4$	=	1·382 „
„ As_2S_3	=	·3371 „

These give a percentage composition agreeing closely with the formula $4PbS.3As_2S_3$[1]:—

	Found.	Calculated.
Pb	48·86	48·75
S	24·39	24·61
As	26·42	26·64
	99·67	100·00

The density of the crystals used had been determined as 5·329.

Of the previous analyses made on Binnenthal sulpharsenites of lead, the following one by Uhrlaub in 1855 (No. 8 in the table of analyses, Min. Mag., 1900, vol. xii, 287) appears to be referable to baumhauerite:—

Pb.	S.	As.	Ag.	Total.	Sp. gr.
47·58	24·66	25·74	0·94	98·92	5·405

Dufrenoysite, $2PbS.As_2S_3$.

Literature.

Damour, 1845, Ann. Chim. Phys., ser. 3, vol. xiv, p. 379. Analyses.
Von Waltershausen, 1855, Ann. Phys. Chem. (Poggendorff), vol. xciv, p. 115. Characters and Analyses.
Des Cloizeaux and Marignac, 1855, Ann. des Mines, ser. 5, vol. viii, p. 389. Crystallography.
Vom Rath, 1864, Ann. Phys. Chem. (Poggendorff), vol. cxxii, p. 373. Characters.
Berendes, 1864, Inaug.-dissert. Bonn. Analyses.
Baumhauer, 1894, Zeits. Kryst. Min., vol. xxiv, p. 85. Crystallography.
König, 1894, Zeits. Kryst. Min., vol. xxiv, p. 86. Analysis.
Baumhauer, 1897, Zeits. Kryst. Min., vol. xxviii, p. 551. Crystallography.
Guillemain, 1898, Inaug.-dissert. Breslau. Analyses.

The name dufrenoysite was given by Damour in 1845 after the French mineralogist P. A. Dufrénoy. From his analyses (see p. 167) of the massive material, he deduced the formula $2PbS.As_2S_3$, but, as pointed out by von Waltershausen in 1855, he made his crystallographic observations on the cubic mineral binnite (=tennantite).

[1] This formula, $4PbS.3As_2S_3$, has previously been assigned by Jackson to the new Binnenthal mineral liveingite, of which I have given a preliminary description in Proc. Cambridge Phil. Soc., 1901, vol. xi, p. 239. The analysis of liveingite agrees, however, more closely with the formula $5PbS.4As_2S_3$.

Waltershausen, in 1855, figured a crystal which may be either dufrenoysite, baumhauerite or rathite; it cannot be sartorite on account of the large development of the (010) and (101) faces. The density he gives is 5·393, which agrees fairly well with that of baumhauerite (5·330), but the amount of lead (44·56 per cent.) found by Uhrlaub indicates a mineral lying between sartorite (Pb = 42·68) and baumhauerite (Pb = 48·75).

Des Cloizeaux and Marignac in 1855 described three crystals under the name of dufrenoysite. One of their crystals, of which a drawing is given [1], was of a large size, measuring $33 \times 12 \times 7$ mm.; it had dull and rough faces, but with the hand-goniometer measurements were obtained, which agreed, Des Cloizeaux states, with the angles measured by Heusser on a sartorite crystal which he called binnite. Below is a comparison of these angles with vom Rath's calculated values for sartorite.

Des Cloizeaux (Dufrenoysite).	vom Rath (Sartorite).
$p : a^{\frac{1}{2}} = 31° 50'$	$001 : 011 = 31° 45'$
$p : a^{\frac{2}{3}} = 51 \quad 9$	$001 : 021 = 51 \quad 4$

Vom Rath, in his paper on dufrenoysite, considered this large crystal of Des Cloizeaux's, on account of its size and cleavage, to be dufrenoysite. If, however, importance is to be attached to the measurements of the dome zone, the crystal must be sartorite, as these dome planes are an invariable guide in distinguishing this species. The size is also not unusual for sartorite; I have some crystals nearly as large. The other two crystals described and figured (figs. 3, 3*a*, and 4) by Des Cloizeaux and Marignac are without doubt jordanite. Their fig. 3 represents a jordanite crystal twinned about $(10\bar{1})$ $(= g^1$ of Des Cl.); the plane (010) $(= p$ of Des Cl.) shows characteristic twin lamination, which however is absent in the zone $[010,101]$ $(= [p, m]$ of Des Cl.). Des Cloizeaux lays much stress upon the existence of two cleavages p, good, and g^1, less perfect, at right angles to one another; I have pointed out (Min. Mag. xii, p. 294) similar cleavages, (010) and $(10\bar{1})$, for jordanite.

Vom Rath says in his paper that he knows of only four crystals of dufrenoysite. (1) A crystal measuring 20×8 mm., in the possession of Herr Wiser of Zurich, which was brought from the Binnenthal by Dr. Ch. Heusser and lent to vom Rath for measurement. (2) A very large crystal, belonging to Dr. Jordan, over 25 mm. across and weighing 18·5 grams. Vom Rath considered the low density (5·337)

[1] Fig. 2, plate vii of the memoir quoted above.

of the crystal to be due to the cavities it contained. This crystal, he says, has a habit similar to Wiser's crystal. The faces are dull, rough, and pitted, but the horizontal striae on the (111) faces are distinct. Vom Rath does not seem to have been able to measure this crystal; I think it is most probably baumhauerite, not dufrenoysite. (3) Another crystal, about 25 mm. across, was goniometrically measured, and a portion of it was used for analysis. Sp. gr. = 5·569. The percentage of lead found by Berendes was 53·62 and 52·02, while 57·18 is required by the dufrenoysite formula. He considered the deficiency in the lead to be due to loss in analysis. (4) A smaller crystal, now in the Royal University Museum at Berlin; of this crystal he gives no details.

Baumhauer, in 1894, described some loose crystals with rounded terminal faces and with striated and channelled prisms; on one end of some of the crystals the (110) faces are developed. With the hand-goniometer the angle between 100 : 110 was measured as 42° to 43°. He found the density to be 5·553. The only measurements obtained on the reflecting goniometer were from small crystal fragments lining cavities in the large rough crystals. One of the large crystals was analysed by Professor König, who found that the chemical composition agreed closely with the theoretical one required for dufrenoysite.

Baumhauer in 1897 described a large crystal measuring $18 \times 18 \times 6$ mm. It is deeply striated and furrowed parallel to the macrodiagonal, and on it he recorded eleven new forms.

Guillemain in 1898 gave the results of an analysis confirming the accepted formula of dufrenoysite.

It will be seen from the above summary of the literature that dufrenoysite is a comparatively rare mineral, and that the crystals are usually of a large size.

The axial ratios calculated by vom Rath from his measured angles $001 : 023 = 45° 35'$ and $001 : 101 = 58° 30'$ are $a : b : c = 0{\cdot}9381 : 1 : 1{\cdot}5309$. The present examination of eight crystals proves, however, that this mineral does not crystallize in the rhombic system but in the *oblique* system with the elements:—

$$a : b : c = 0{\cdot}650987 : 1 : 0{\cdot}612576; \quad \beta = 90° 33\tfrac{1}{2}'$$

as calculated from $100 : 101 = 47° 2\tfrac{1}{4}'$, $101 : 001 = 43° 31\tfrac{1}{4}'$ and $010 : 212 = 77° 22'$ measured on crystal No. I (p. 167), which gives very sharp reflected images.

The plane (001) of vom Rath is the plane of symmetry (010), his (100) becomes (001), and (010) becomes (100). The parametral plane (111) remains unchanged.

The crucial zone [100,001] is well developed on crystals I and IV, and the faces give very sharp reflections, but as a rule this zone is ill-defined and has rough faces. The pyramid planes in the + and — zones are seldom equally developed, and often only one of these zones is present on the crystals: the face (111) is usually smooth, while (11$\bar{1}$) is deeply striated parallel to the zone-axis [110].

The crystals are sometimes aggregated together in a manner resembling that of twin aggregations: these are described under crystal VI (p. 170).

The following table brings together for comparison the measurements obtained by vom Rath, Baumhauer and myself of the principal faces in the important zones.

	Calculated (Solly).	Rath 1st crystal.	Rath 2nd crystal	Baumhauer 1st crystal.	Baumhauer 2nd crystal.	Solly crystal I.	„ II.	„ III.	„ IV.	„ V.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
100 : 101	47 2½			46 56		47 2			47	
: 10$\bar{1}$	46 26¾						46 26			46 27
101 : 001	43 31¼	43 15		43 0	43°–44°	43 31				
$\bar{1}$01 : 00$\bar{1}$	42 59¾						43 0			42 59
010 : 120	37 31½	37 15		37 24½	37°38′	37 31	37 30	37 31	37 30	37 32
: 230	45 41	45 35		45 38	45 26	45 41		45 41	45 40	45 43
: 110	56 56¼	56 46				57 0	56 58		56 56	
: 021	39 13	39 10	39 12	39 14	39 53	39 13	39 12	39 16		39 14
: 032	47 25	47 24	47 11½	47 22½	47 31	47 25	47 23	47 25		47 24
: 011	58 30¼	58 30	58 29	58 33½	57 58½	58 30½	58 29	58 30		58 29
: 012	72 58½	72 58		72 57	72 25	72 57	72 58	73 0		72 50
: 232	56 5			56 12		56 4			56 3	
: $\bar{2}$32	56 20						56 25	56 23		56 21
: 111	65 51¼	65 54		65 51½		65 50			65 51	
: $\bar{1}$11	66 3½						66 3	66 4	66 4	66 3
: 212	77 22	77 29		77 19	77 18	77 22				
: $\bar{2}$12	77 29			77 32½			77 29	77 30		77 29

The planes in the zone [010,101] are usually small, smooth, or finely striated parallel to their intersections, and are associated with numerous minute pyramid planes; while the planes in the zone [010,10$\bar{1}$] are often largely developed, deeply striated or furrowed, with dull rough surfaces, and sometimes accompanied by planes in the zone [010,20$\bar{1}$]. The planes in the zone [100,010] are very numerous and some of them have high indices; this may be due to a tendency on the part of the crystal to repeated twinning about a plane inclined at a small angle to (010): such distortion in the position of the planes in this zone is often seen in a similar zone on rathite. The planes in the zone [010,001] are very numerous and usually exhibit fine striations parallel to their intersections

with one another. The planes (210), (032), (012), (011) are large; while (410), (530), (052), (031) are medium in size; (110) is often well developed, but rough or pitted. The clinopinacoid (010) is sometimes large and smooth, but sometimes small and finely striated, parallel to the zone-axis [100]. The pinacoids (100), (001) are occasionally well developed, and the former shows distinct unsymmetric markings as is illustrated in fig. 6.

Table III contains the list of ninety-nine known forms, of which

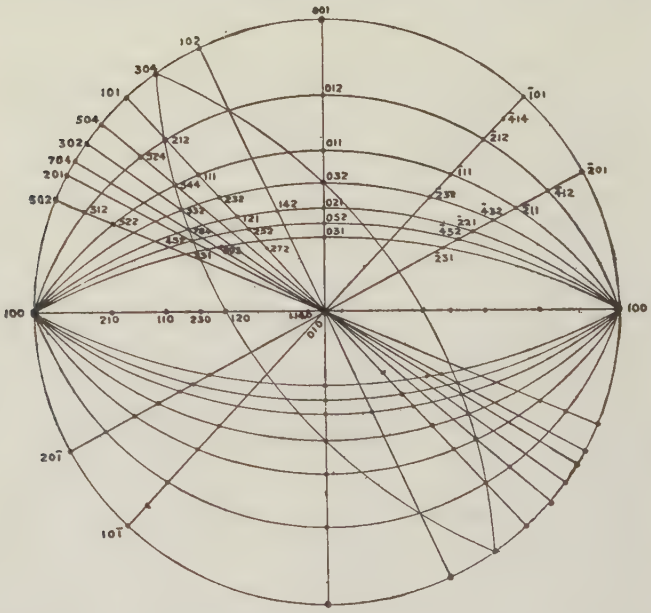

FIG. 5.—Stereographic projection of dufrenoysite, showing most of the observed forms.

seventeen had been recorded by vom Rath and eleven by Baumhauer. Baumhauer's planes (027) = (270) and (049) = (490) I have not found. The positions of many of the forms are indicated in the stereographic projection, fig. 5.

There are two distinct habits:—

Habit I. The crystals are elongated parallel to the zone-axis [100]; the plane (010), parallel to the direction of cleavage, is large and smooth.

The zone [010,001] is largely developed, while the zone [100,010] is small; the pyramid zones are absent or ill-defined (fig. 8).

Habit II. The crystals are elongated along the axis of symmetry; (010) is small and finely striated parallel to its intersections with (001). In the zone [100,001] the planes (100), (101), (001), (10$\bar{1}$) are well developed.

TABLE III.—LIST OF FORMS OBSERVED ON DUFRENOYSITE.

Symbols.	Indices.	Rath.	Baumhauer.	Symbols.	Indices.	Rath.	Baumhauer.	Symbols.	Indices.	Rath.	Baumhauer.
a	100	b		$\frac{4}{3}s$	430			$\frac{1}{8}l$	018		
b	010	c		$\frac{8}{3}s$	530			$\frac{1}{4}l$	014		
c	001	a		$2s$	210			$\frac{1}{3}l$	015		
$-h$	101	m		$3s$	310			$\frac{1}{2}l$	016		
$+h$	10$\bar{1}$			$4s$	410			$\frac{1}{5}l$	019		
$-\frac{3}{2}h$	502			$6s$	610						
$-2h$	201			$14s$	14·1·0			$-\frac{7}{2}q$	272		
$+2h$	20$\bar{1}$							$-\frac{5}{2}q$	252		
$-\frac{7}{4}h$	704			$9k$	091			$-2q$	121		
$-\frac{3}{2}h$	302			$8k$	081			$-\frac{3}{2}q$	232		$\frac{1}{3}P$
$-\frac{5}{4}h$	504			$\frac{11}{2}k$	0·11·2			$+\frac{3}{2}q$	232		
$-2i$	102			$5k$	051			$-p$	111	o	
				$\frac{9}{2}k$	092			$+p$	11$\bar{1}$		
$14r$	1·14·0			$4k$	041	$\frac{1}{4}d$		$-2t$	212	$2o$	
$5r$	150			$\frac{7}{2}k$	072		207	$+2t$	21$\bar{2}$		
$\frac{7}{2}r$	270		027	$3k$	031		103	$+\frac{3}{2}t$	343		
$3r$	130		013	$\frac{11}{4}k$	0·11·4			$-4t$	414		441
$\frac{5}{2}r$	250		025	$\frac{5}{2}k$	052		205	$+4t$	41$\bar{4}$		
$\frac{1}{2}r$	490		049	$\frac{7}{3}k$	073			$-y$	522		
$2r$	120	$\frac{1}{2}f$		$\frac{8}{3}k$	094			$-\frac{1}{2}y$	512		
$\frac{5}{3}r$	590			$\frac{11}{6}k$	0·11·5			$-3u$	231		
$\frac{7}{4}r$	470		047	$2k$	021	$\frac{1}{2}d$		$+3u$	23$\bar{1}$		
$\frac{5}{3}r$	350			$\frac{15}{8}k$	0·15·8			$-\frac{5}{2}u$	452		
$\frac{8}{3}r$	580			$\frac{7}{4}k$	074			$+\frac{5}{2}u$	45$\bar{2}$		
$\frac{3}{2}r$	230	$\frac{2}{3}f$		$\frac{17}{10}k$	0·17·10			$+2u$	22$\bar{1}$		
$\frac{7}{5}r$	570			$\frac{5}{3}k$	053			$+\frac{5}{2}u$	43$\bar{2}$		
$\frac{4}{3}r$	340			$\frac{8}{3}k$	032	$\frac{2}{3}d$		$+u$	21$\bar{1}$		
$\frac{5}{2}r$	450			$\frac{4}{3}k$	043			$+\frac{1}{2}u$	41$\bar{2}$		
$\frac{8}{5}r$	560			$\frac{5}{3}k$	054			$-3z$	33$\bar{2}$		
$\frac{6}{5}r$	670			k	011	d		$-v$	54$\bar{4}$		
$\frac{11}{11}r$	11·12·0			$\frac{5}{4}l$	056			$-\frac{1}{2}v$	52$\bar{4}$		
r	110	f		$\frac{3}{2}l$	034			$-8Z$	78$\bar{4}$		
$\frac{11}{11}s$	12·11·0			$\frac{5}{6}l$	035			$-9Y$	59$\bar{8}$		
$\frac{1}{6}s$	760			$\frac{1}{4}l$	012	$2d$		$-4n$	14$\bar{2}$		

TABLE IV.—CALCULATED ANGLES OF DUFRENOYSITE.

	° ′
Zone [100,001]	
100 : 502	= 23 7
: 201	= 28 6½
: 704	= 31 24
: 302	= 35 30
: 504	= 40 36
: 101	= 47 2½
: 102	= 65 15½
: 001	= 90 33½
100 : 20$\bar{1}$	= 27 51½
: 10$\bar{1}$	= 46 26½
: 00$\bar{1}$	= 89 26½
Zone [010,100]	
010 : 1.14.0	= 6 15½
: 150	= 17 5
: 270	= 23 40½
: 130	= 27 7
: 250	= 31 34
: 490	= 34 19
: 120	= 37 31½
: 590	= 40 28½
: 470	= 41 16½
: 350	= 42 40
: 580	= 43 50
: 230	= 45 41
: 570	= 47 39
: 340	= 49 2½
: 450	= 50 52
: 560	= 52 0
: 670	= 52 47
: 11.12.0	= 54 37
: 110	= 56 56¼
: 12.11.0	= 59 10½
: 760	= 60 50

	° ′
010 : 430	= 63 58½
: 530	= 68 40
: 210	= 71 58
: 310	= 77 45½
: 410	= 80 45½
: 610	= 83 48½
: 14.1.0	= 87 20
Zone [010,001]	
010 : 091	= 10 16½
: 081	= 11 32
: 0.11.2	= 16 31½
: 051	= 18 4
: 092	= 19 56
: 041	= 22 12
: 072	= 25 0
: 031	= 28 33
: 0.11.4	= 30 41½
: 052	= 33 8½
: 073	= 34 58½
: 094	= 35 57½
: 0.11.5	= 36 34½
: 021	= 39 13
: 0.15.8	= 41 2½
: 074	= 43 0½
: 0.17.10	= 43 50
: 053	= 44 24
: 032	= 47 25
: 043	= 50 45½
: 054	= 52 33½
: 011	= 58 30½
: 056	= 62 57½
: 034	= 65 19½
: 035	= 69 49
: 012	= 72 58

	° ′
010 : 013	= 78 27½
: 014	= 81 17½
: 015	= 83 0
: 016	= 84 10
: 019	= 86 6
Zone [010,101]	
010 : 27$\bar{2}$	= 32 31
: 25$\bar{2}$	= 41 44½
: 12$\bar{1}$	= 48 7
: 23$\bar{2}$	= 56 5
: 11$\bar{1}$	= 65 51½
: 21$\bar{2}$	= 77 22
: 41$\bar{4}$	= 83 36½
Zone [010,10$\bar{1}$]	
010 : 23$\bar{2}$	= 56 20
: 34$\bar{3}$	= 59 24
: 11$\bar{1}$	= 66 3½
: 21$\bar{2}$	= 77 29
: 41$\bar{4}$	= 83 40
Zone [010,102]	
010 : 14$\bar{2}$	= 41 56½
Zone [010,504]	
010 : 54$\bar{4}$	= 68 15½
: 52$\bar{4}$	= 78 43½
Zone [010,302]	
010 : 33$\bar{2}$	= 61 55
Zone [010,704]	
010 : 78$\bar{4}$	= 57 26½
Zone [010,201]	
010 : 23$\bar{1}$	= 49 6½
: 45$\bar{2}$	= 54 11½
: 22$\bar{1}$	= 60 0½
: 43$\bar{2}$	= 66 35½
: 21$\bar{1}$	= 73 54

	° ′
010 : 412	= 81 47½
Zone [010,20$\bar{1}$]	
010 : 23$\bar{1}$	= 49 20
: 45$\bar{2}$	= 54 24
: 22$\bar{1}$	= 60 8½
: 43$\bar{2}$	= 66 45½
: 21$\bar{1}$	= 74 1½
: 41$\bar{2}$	= 81 51
Zone [010,502]	
010 : 52$\bar{2}$	= 76 28½
: 51$\bar{2}$	= 83 8½
Zone [100,012]	
100 : 51$\bar{2}$	= 24 3½
: 52$\bar{4}$	= 41 53½
: 21$\bar{2}$	= 48 19
: 01$\bar{2}$	= 90 32
: $\bar{2}$12	= 132 17
: $\bar{4}$12	= 151 4
Zone [100,011]	
100 : 52$\bar{2}$	= 26 35½
: 54$\bar{4}$	= 45 9
: 11$\bar{1}$	= 51 33
: 01$\bar{1}$	= 90 28½
: $\bar{1}$11	= 129 2
: $\bar{2}$11	= 148 13
Zone [001,210]	
001 : 21$\bar{2}$	= 44 58
: 21$\bar{0}$	= 90 31½
: 21$\bar{1}$	= 117 13
: 21$\bar{2}$	= 133 33½
Zone [001,110]	
001 : 11$\bar{1}$	= 48 34½
: 11$\bar{0}$	= 90 28
: 11$\bar{1}$	= 131 56½

The physical characters to be noted are the following:—

The colour is lead-grey to steel-grey, and the crystals are seldom tarnished. Streak chocolate colour. Opaque. There is a perfect cleavage parallel to the plane of symmetry (010). Hardness 3. Specific gravity 5·569 (vom Rath), 5·553 (Baumhauer), 5·52 (König), 5·50 (Solly).

Respecting the mode of occurrence, it may be noted that dufrenoysite is found only in isolated crystals in the dolomite or in cavities with similar crystals, unaccompanied by the other minerals commonly found in the dolomite. According to previous observers, only large crystals have been found, while those found since 1898 are small or moderately large. The only known locality is the bed of the Lengenbach, Binnenthal.

The published chemical analyses which have been made of dufrenoysite are collected together in the following table:—

	Pb.	S.	As.	Ag.	Cu.	Fe.	Total.
$2PbS.As_2S_3$	57·18	22·10	20·72				100·00
König	57·42	22·55	20·89				100·86
Guillemain	57·38	21·94	21·01				100·33
„	56·73	21·18	20·04				97·95
Damour	56·61	22·30	20·87	0·17	0·22	0·32	100·49
„	55·40	22·49	20·69	0·21	0·30	0·44	99·53
Berendes	53·62	23·27	21·76	0·05		0·30	99·00
„	52·02	23·11	21·35				96·48

Description of Specimens.

The crystallographic observations have been made on eight loose crystals; three crystals on the matrix of dolomite were also examined. All of them have been found since 1898.

The largest specimen is an aggregation of a number of fine crystals resembling habit I; the largest crystal of the group measures about 15 mm. in length and the same in breadth. A small crystal which is described as No. VII was removed from this specimen.

Crystal I. (Fig. 6.)

This crystal, found in 1901, is remarkably brilliant; the planes are very smooth and give sharp reflections. The size is $13 \times 10 \times 5$ mm. It is elongated along the axis of symmetry, and (010) is small (habit II).

	Calculated.	Measured.		Calculated.	Measured.
Zone [010,100].					
010 : 130	= 27° 7′	27° 5′	010 : 110	= 56°56¼′	57°
: 120	= 37 31½	37 31	: 12.11.0	= 59 10½	59
: 590	= 40 28½	40 28½	: 760	= 60 50	61
: 470	= 41 16½	41 16	: 530	= 68 40	68 40
: 580	= 43 50	43 50	: 210	= 71 58	71 57
: 230	= 45 41	45 41	: 310	= 77 45½	77 45
: 570	= 47 39	47 39	: 410	= 80 45½	80 45
: 340	= 49 2½	49 2	: 610	= 83 48½	83 48
: 560	= 52 0	52 0	: 14.1.0	= 87 20	87 21
: 670	= 52 47	52 47	: 100	= 90 0	90 0
: 11.12.0	= 54 37	54 40			

The planes (100) and (210) are large. The plane (2$\bar{1}$0) has a deep furrow across the centre of the face, apparently parallel to the zone-axis [120]. This furrow has been observed on two other crystals; that it is intimately

connected with the growth of the crystal is certain, but its crystallographic significance cannot be determined at present.

	Calculated.	Measured.		Calculated.	Measured.
Zone [010,001]					
010 : 031	=28°33	28°33′	010 : 054	=52°33½′	52°32′
: 0.11.4	=30 41½	30 41	: 011	=58 30½	58 30½
: 052	=33 8½	33 8	: 056	=62 57½	63
: 094	=35 57½	35 57	: 034	=65 19½	65 18
: 021	=39 13	39 13	: 012	=72 58½	72 58
: 0.15.8	=41 2½	41	: 013	=78 27½	78 27
: 074	=43 0½	43	: 014	=81 17½	81 17
: 032	=47 25	47 25	: 016	=84 10	84 10
: 043	=50 45½	50 45	: 001	=90 0	90 0

The planes (021), (032), (011), (012) are well developed.

	Measured.		Measured.
Zone [100 : 001]			
100 : 101	=*47° 2¼	101 : 001	=*42° 31¼

The planes (100), (101), (001) are well developed. There are some very small planes between (100) and (101) which are probably (502), (201), (704), (302) and (504), but I could obtain no distinct images.

	Calculated.	Measured.		Calculated.	Measured.
Zone [010,101]					
010 : 252	=41°44½′	41°44′	010 : 111	=65°51¼′	65°50′
: 121	=48 7	48 7	: 212	= —	*77 22
: 232	=56 5	56 4	: 101	=90 0	90 0

The plane (212) is very good, and the others are well defined. There are also other small pyramid planes. The planes (544), (524), (332), (784), (452), (522), and (512) were determined by measurement and zones.

	Calculated.	Measured.		Calculated.	Measured.
Zone [100,012]			Zone [100,011]		
100 : 512	=24° 3½′	24°	100 : 522	=26°35½′	27°
: 524	=41 53½	41 50	: 544	=45 9	45
: 212	=48 19	48 19	: 111	=51 33	51 35
: 012	=90 32	90 32	: 011	=90 28½	90 28
Zone [100,021]			Zone [100,052]		
100 : 784	=44 1	43	100 : 452	=44 20	44 15
: 121	=59 30½	59 30	: 252	=63 1	63 0
: 021	=90 21	90 21	: 052	=90 18½	90 19

Zone [304,120] contains the planes (212), (544), (332), (784), (452) and (120).

Zone [010,504] „ „ (524), (544).

Zone [010,502] „ „ (522), (512).

Crystal II. (Fig. 7.)

This crystal I found in 1898; it belongs to habit II. The pyramids $+(11\bar{1})$ and $+(21\bar{2})$ are well developed, while in the negative octant the faces are small. The zone [010,100] is largely developed; [010,001] is medium in size. The plane (010) is small and finely striated parallel to the direction of the zone-axis [100]. The following planes are present:— (010), (001), (091), (052), (094), (0.11.5), (074), (0.17.10), (032), (011), (035), (012), (015), (019), (250), (120), (350), (230), (110), (272), (121), $(23\bar{2})$, $(11\bar{1})$, $(21\bar{2})$, $(10\bar{1})$, (142), (231), (593). The plane (272) is rough and lies in the zone [032,120].

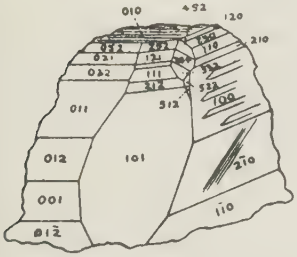

FIG. 6.

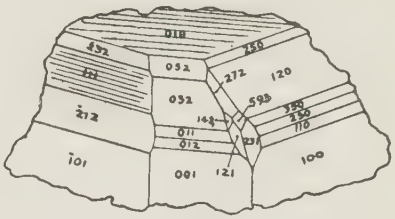

FIG. 7.

Dufrenoysite (Habit II).

	Calculated.	Measured.		Calculated.	Measured.
$001:\bar{1}01$	$=42°59\frac{3}{4}'$	43° 0′	$010:23\bar{2}$	$=56°20'$	56°18′
$010:091$	$=10\ 16\frac{1}{2}$	10 16	$:11\bar{1}$	$=66\ 3\frac{1}{2}$	66 3
$:0.11.5$	$=36\ 34\frac{1}{2}$	36 32	$:21\bar{2}$	$=77\ 29$	77 29
$:0.17.10$	$=43\ 50$	43 53	$:10\bar{1}$	$=90\ 0$	90
$:035$	$=69\ 49$	69 50	$:142$	$=41\ 57\frac{1}{2}$	41 57
$:015$	$=83\ 0$	83 1	$:231$	$=49\ 6\frac{1}{2}$	49 6
$:019$	$=86\ 6$	86 5	$:593$	$=45\ 13\frac{1}{2}$	45 14
$:250$	$=31\ 34$	31 33			
$:350$	$=42\ 40$	42 43			

Crystal III.

A small rounded crystal of habit II.

The following planes are present :—(010), (120), (230), (450), (110), (011), (056), (034), (012), (23$\bar{2}$), (11$\bar{1}$), (21$\bar{2}$), (10$\bar{1}$).

	Calculated.	Measured.
010 : 450 =	50°52′	50°50′
: 11$\bar{1}$ =	66 3½	66 4
: 21$\bar{2}$ =	77 29	77 30

Crystal IV.

A small crystal of habit II with well developed (111) and (11$\bar{1}$), and small (101), (010); the other planes present are (100), (470), (230), (560), (110), (210), (410), (252), (121), (232), (011), (034), (012). The plane (111) is smooth, while (11$\bar{1}$) is striated parallel to the zone-axis [$\bar{1}$10].

	Calculated.	Measured.
100 : 101 =	47° 2¼′	47° 0′
111 : 110 =	41 53½	41 53
110 : 11$\bar{1}$ =	41 28½	41 29

Crystal V.

A small but highly modified crystal of habit II. The faces in the positive octant are well developed. The following planes are present :—(010), (100), (001), (150), (120), (230), (670), (110), (430), (210), (310), (410), (20$\bar{1}$), (10$\bar{1}$), (021), (0.15.8), (074), (0.17.10), (053), (032), (011), (034), (012), (23$\bar{1}$), (45$\bar{2}$), (22$\bar{1}$), (43$\bar{2}$), (21$\bar{1}$), (41$\bar{2}$), (23$\bar{2}$), (34$\bar{3}$), (11$\bar{1}$), (21$\bar{2}$), (41$\bar{4}$).

	Calculated.	Measured.		Calculated.	Measured.
010 : 150 =	17° 5′	17° 3′	010 : 45$\bar{2}$ =	54°24′	54°25′
: 430 =	63 58½	64 0	: 22$\bar{1}$ =	60 8½	60 7
: 053 =	44 24	44 25	: 43$\bar{2}$ =	66 45½	66 45
100 : 20$\bar{1}$ =	27 51½	27 51	: 21$\bar{1}$ =	74 1½	74 1
: 10$\bar{1}$ =	46 26¾	46 27	: 41$\bar{2}$ =	81 51	81 52
: 00$\bar{1}$ =	89 26½	89 26	: 34$\bar{3}$ =	59 24	59 26
010 : 23$\bar{1}$ =	49 20	49 21	: 41$\bar{4}$ =	83 40	83 41

Crystal VI. (Fig. 8.)

This crystal is typical of habit I. The face (010) is large, and the crystal is elongated along the zone-axis [100]. The zone [010,001] is largely developed and finely striated parallel to the zone-axis [100].

Attached to this crystal is a smaller one, which may be a twin growth resembling a growth observed on rathite (Solly, this Magazine, vol. xiii, p. 80). Two distinct images were observed on $\bar{0}10$.

	Calculated.	Measured.
010 : $\bar{0}10$ twinned about (1.14.0) =	11°42′	11°57′
„ „ „ (1.15.0) =	12 26	12 21

The planes (001) of each crystal are nearly parallel to one another, but the planes (010), ($\overline{0}10$) do not exactly lie in the zone [010,100]. If the crystal were twinned about (001) and (1.14.0) or (1.15.0), such an aggregation as is seen on this crystal VI would be formed. On crystals VII and VIII similar aggregations are found, but the angle between 010 : $\overline{0}10$ is 2° 2′ and 1° 12′.

The following planes are present:—(010), (081), (092), (041), (072), (031), (052), (021), (0.15.8), (053), (032), (054), (011), (056), (034), (012), (013), (014), (001), (250), (120), (230), (252), (232), (11$\bar{1}$), (21$\bar{2}$).

Calculated.	Measured.	Calculated.	Measured.
010 : 081 = 11°32′	11°31′	010 : 072 = 25° 0′	25° ′
: 092 = 19 56½	19 55	11$\bar{1}$: 21$\bar{2}$ = 11 25½	11 25
: 041 = 22 12	22 12		

FIG. 8.—Dufrenoysite (Habit I).

Crystal VII.

This crystal of habit I was removed from the large specimen mentioned on page 167. The face (010) is large; the zone [010,10$\bar{1}$] is deeply striated; the zone [010,101] is small and rough. It exhibits an aggregation similar to crystal VI, as described above.

The following planes are present:—(010), (052), (021), (032), (011), (012), (001), largely developed; (091), (0.11.2), (051), (092), (041), (072), (031), (073), (074), (043), (054), (056), (034), small.

Calculated.	Measured.
010 : 0.11.2 = 16°31½′	16°31′
: 051 = 18 4	18 3
: 073 = 34 58½	34 59

Crystal VIII.

Similar to crystal VII. It exhibits an aggregation similar to VI, as described above.

On Gibbsite from the Palni Hills in Southern India.

By H. Warth, D.Sc.

Late Deputy Superintendent, Geological Survey of India.

(Communicated by F. R. Mallet.)

[Read November 12, 1901.]

THE mineral described below was found by the present writer, in the year 1893, at Kodikanal on the Palni Hills, in the Madura District of the Madras Presidency. These hills, which rise at Kodikanal to a height of 7000 feet above the sea, form a range some thirty miles long in a WSW.–ENE. direction, with a breadth about half as great. They are composed of grey igneous rock, belonging to Mr. T. H. Holland's 'Charnockite' series, the slight foliation being in a direction coincident with that of the range, while the dip is at high angles. The mountains are at present mostly clothed with grass only, the soil being highly charged with peaty matter, and moderately fertile.

It is between this soil and the underlying rock that the mineral in question occurs, forming a loose bed about one foot thick. The bed was seen to be continuous throughout excavations which had been made over an area of several acres for planting purposes.

The mineral is perfectly amorphous, and takes the form of nodular plates up to half an inch in thickness. It becomes polished on rubbing with the fingers, and owing to its porosity it adheres readily to the tongue. The specific gravity is 2·42, and the colour nearly white with a cream or reddish tint.

On analysis of a pulverized sample, dried slightly above 100° C., I obtained the following results:—

	Found.	Calculated to 100.	Theory. ($Al_2O_3.3H_2O$).
H_2O . . .	33·74	34·95	34·58
Al_2O_3 . . .	62·80	65·05	65·42
Fe_2O_3 . . .	0·44	100·00	100·00
CaO . . .	0·20		
MgO . . .	0·03		
SiO_2 . . .	2·78		
TiO_2 . . .	0·04		
	100·03		

The approximation to the theoretical composition of gibbsite ($Al_2O_3.3H_2O$) is therefore very close, and would be somewhat closer still if the ferric oxide were regarded as replacing an equivalent amount of alumina. Whatever part, however, it may have played originally, the ferric oxide now seems, in the main at least, to exist as an impurity, being chiefly concentrated in the minute fissures and cavities of the mineral. So far as I am aware, this is the first observed occurrence of gibbsite in India.

The mineral dissolves easily in hot, somewhat concentrated, sulphuric acid, and in hot sodium hydrate solution; less perfectly in hot hydrochloric acid. In the cold these solvents act very slowly. To determine the action of the reagents mentioned, I treated six portions of the pulverized mineral, each weighing one gram, with solvent, and after washing and igniting the residues, calculated the percentages of the original hydrous mineral corresponding to them :—

Solvent.	Temperature.	Duration of treatment.	Mineral left undissolved.
H_2SO_4 (sp. gr. 1·35)	boiling	5 minutes	3·8 per cent.
H_2SO_4 (sp. gr. 1·35)	cold	2 hours	57·7 „
HCl (sp. gr. 1·10)	boiling	5 minutes	20·7 „
HCl (sp. gr. 1·10)	cold	2 hours	83·7 „
NaOH (conc. sol.)	boiling	5 minutes	2·1 „
NaOH (conc. sol.)	cold	2 hours	86·9 „

The mineral does not decrepitate when heated in fragments. After ignition before the blowpipe, it scratched quartz and the specific gravity increased to 3·68. The pulverized mineral heated over the blowpipe became snow-white after cooling, notwithstanding the iron present[1].

In respect to origin, the mineral would seem to be a product of atmospheric decomposition of the underlying igneous rock. The composition of gibbsite is the same as that of the precipitate which forms when a current of carbon dioxide is passed through a solution of sodium aluminate, as in the technical preparation of pure alumina from bauxite. In the case of the Indian mineral, some alkaline aluminate may have been derived from the weathering rock, and acted on in dilute solution beneath the soil by carbon dioxide dissolved in percolating water, the alumina being thus precipitated as gibbsite.

[1] Cf. Chemical News, 1901, vol. lxxxiv, p. 305.

The Cerargyrite Group (holohedral-cubic silver haloids).

By G. T. Prior, M.A., F.G.S. and L. J. Spencer, M.A., F.G.S.
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[Read February 4, 1902.]

Historical Introduction.—As given in modern text-books, the holohedral-cubic silver haloids occurring as minerals include the following species: the pure chloride, chlorargyrite, AgCl.; the pure bromide, bromargyrite, AgBr; the intermediate embolite, Ag(Cl,Br), containing chlorine and bromine in varying proportions; and iodobromite, containing all three halogens in a definite ratio corresponding to the formula 2AgCl.2AgBr.AgI.

The terms hornsilver (used by Gesner as far back as 1565) and cerargyrite (Beudant, 1832) are usually taken as referring only to the pure chloride. As regards their signification, however, they are equally applicable to all of the above species, and in lack of chemical analyses were certainly so applied in the past. Thus Breithaupt, after the discovery of the bromide and chloro-bromide of silver by Berthier in 1841 and 1842, remarks that many of the specimens of 'Hornerz' in the Werner Museum having a greenish colour probably contained bromine. The new bromide and chloro-bromide, together with the chloride of silver, were included by Breithaupt in the genus 'Cerargyrites.' In the present note we propose to so far revive this idea as to refer to all the holohedral-cubic silver haloids under the general name of cerargyrite.

To the chloro-bromide analysed by Plattner in 1849, and having the chemical composition expressed by the formula 3AgCl.2AgBr, Breithaupt gave the name embolite. That he regarded embolite as a definite species with this particular composition is evident from the fact that to two other chloro-bromides, described by him in 1859 and showing different proportions of the two halogens, he gave the distinct specific

names megabromite (4AgCl.5AgBr) and microbromite (3AgCl.AgBr). Later analyses of chloro-bromides by Beck, Munro, Wood, and Field led to still other formulae, so that in 1886 it was pointed out by Welch that of fourteen published analyses, four corresponded more or less closely to 3AgCl.2AgBr, two to 5AgCl.2AgBr, and one to AgCl.AgBr, while seven called each for a separate formula. It has been recognized therefore that in these chloro-bromides the proportion of chloride and bromide may vary considerably. Embolite thus ceases to be a very definite species, since it may pass indefinitely, on the one hand into chlorargyrite, and on the other into bromargyrite.

It is one of the objects of the present paper to show that in the case of silver haloids containing all three halogens this history of embolite is repeating itself. Just as embolite was at first considered to have a fixed, definite chemical composition, so has the iodobromite, from Dernbach in Nassau, described by A. von Lasaulx in 1877[1], been regarded in the text-books as a mineral with the definite formula 2AgCl. 2AgBr.AgI.

Lasaulx claimed that iodobromite was the first mineral to be described as containing all three halogens. In 1869, however, F. A. Moesta[2] published an analysis of a chloro-bromide of silver from Chili showing a small percentage (1·73) of iodine in what would otherwise be described as an embolite. Previous to this, in 1853, Damour[3] had detected iodine in two specimens of olive-green silver bromide from Huelgoat, Brittany; and Dufrénoy in 1856 in his treatise mentions the isomorphous replacement of some of the chlorine by iodine in chlorargyrite from the same locality. Dufrénoy was thus led to consider the existence of a cubic silver iodide as probable, and even described[4] as such some bright yellow crystals on a specimen from Chañarcillo in the Muséum d'Histoire Naturelle in Paris; but as no chemical analysis was made of the crystals, it is probable that they contained all three halogens (see analysis of orange-yellow crystals of silver haloid from Chañarcillo on p. 179 below). More recently, in 1888, after the discovery of the silver ores of Broken Hill, A. Liversidge pointed out[5] that 'all the New

[1] Zeits. Kryst. Min., 1877, vol. i, pp. 506–7; Neues Jahrb. Min., 1878, pp. 619–23 (Abstract in this Magazine, vol. ii, p. 237).

[2] Ueber das Vorkommen der Chlor-, Brom- und Jodverbindungen des Silbers in der Natur (Ein Beitrag zur Kenntniss der geologischen und bergbaulichen Verhaltnisse). Marburg, 1870, 47 pp., 4 plates. (Also as Habilit.-Schrift, Marburg, 1869.)

[3] Ann. des Mines, 1853, ser. 5, vol. iv, p. 332.

[4] Traité de Minéralogie, 2nd edition, 1856, vol. iii, pp. 452, 460.

[5] Journ. and Proc. Roy. Soc. N.S.W., 1888, vol. xxii, p. 365.

South Wales silver chloride specimens' which he had examined 'contain iodine, some only traces, and others a fair percentage.'

In the present paper are given the results of qualitative and quantitative analyses made on very carefully selected material, showing that the chloride, bromide and iodide of silver may occur together in isomorphous mixtures in very varying proportions besides the particular one found by Lasaulx in iodobromite. Accordingly iodobromite, just as embolite, ceases to be a definite species. If the name were retained it might be applied to isomorphous mixtures of chloride, bromide and iodide of silver in which the three halogens are all present in fair amount; but since the name is a particularly misleading one, as suggesting that the mineral only contains iodide and bromide, we propose to refer to the varieties of the cerargyrite group which contain all three halogens as iodiferous embolites or briefly *iodembolites*.

Qualitative examination of Cerargyrites.—In order to test the present method of classification of the silver haloids a qualitative chemical examination was made of thirty-two specimens in the British Museum collection labelled chlorargyrite, bromargyrite, and embolite.

The method of analysis consisted in decomposing the mineral in the usual way by means of zinc and sulphuric acid, so that the silver was deposited and the halogens passed into solution as zinc salts. A portion of this solution was tested for iodine by the addition of one or two drops of a saturated solution of nitrous acid in sulphuric acid, and then for bromine (after the removal of the iodine dissolved in carbon bisulphide) by addition of chlorine water. Another portion of the solution was tested for chlorine by adding either potassium permanganate, or lead peroxide and acetic acid, boiling until all bromine and iodine were expelled, and treating with silver nitrate to precipitate the chlorine. As a confirmatory test a third portion of the original solution was treated with silver nitrate, and the resulting precipitate tested as to its solubility in ammonia.

The result of the qualitative examination given in the following table, showed that none of the specimens labelled bromargyrite consisted of *pure* bromide of silver, that many so-called chlorargyrites contained much bromine, and that many of the specimens referred to embolite contained iodine in varying amounts besides the chlorine and bromine.

Number.	*Locality.*	*Colour.*	*Chlorine.*	*Bromine.*	*Iodine.*
Chlorargyrites:—					
1391	Johanngeorgenstadt	colourless	much	none	none
32977	S. America	,,	,,	,,	,,
36275	Copiapo, Chili	,,	,,	,,	,,
35839	Chili	greenish-yellow tinge	,,	,,	,,
54819	Taltal, Chili	greenish tinge	,,	,,	,,
Embolites:—					
34665	Dolcoath mine, Cornwall	greenish-grey	much	some	none
34293	,,	,,	,,	,,	,,
34295	,,	pale greenish-grey	,,	,,	,,
32133	Chañarcillo	,,	,,	little	,,
44464	,,	greenish-grey	,,	some	,,
34811	,,	,,	some	much	,,
A. G. 11	'Peru'	,,	much	some	,,
37086	Copiapo, Chili	,,	,,	little	,,
A. G. 8	S. America	,,	,,	some	,,
65398	Broken Hill	,,	,,	little	,,
65397	,,	pale greenish-grey	,,	,,	,,
37087	Plateros, Mexico	greenish-grey	very little	much	,,
Iodembolites:—					
83458	Broken Hill	pale greenish-grey	some	some	very little
76235	,,	,,	,,	,,	,,
71533	,,	,,	,,	,,	little
80678	,,	pale greenish-yellow	,,	,,	very little
64379	,,	,,	,,	,,	little
85484	,,	greenish-yellow	,,	,,	,,
64376	,,	,,	,,	little	much
84822	,,	,,	much	some	little
83825	,,	orange-yellow	some	,,	much
44459	Chañarcillo	greenish-yellow	,,	,,	some
35842	,,	,,	,,	little	,,
36280	,,	orange-yellow	,,	some	,,
53925	,,	,,	,,	little	,,
46189	,,	,,	,,	some	little
40661	Catorce, Mexico	pale greenish-yellow	,,	,,	some

Iodembolites.

Four of the specimens which the qualitative examination had shown to contain all three halogens were selected for more detailed investigation and quantitative analysis. The following description of the physical characters applies mainly to the three first well-crystallized specimens (*A, B, C*).

Physical Characters.—The crystals on all three specimens, although differing considerably in chemical composition, are very similar in general appearance. The faces are bright and smooth, but not perfectly plane, so that only approximate measurements can be obtained on the goniometer. The angles measured agree closely enough with cubic angles, and the only forms present are the cube $a\{100\}$ and octahedron $o\{111\}$. On the Broken Hill specimens a few of the crystals are twinned according to the spinel-law. The colour of the crystals of two specimens (*A* and *B*) is bright orange-yellow, that of specimen *C* is greenish-yellow; but this is soon altered to green on exposure to light. The crystals are translucent, and only small fragments allow of the passage of sufficient light for examination under the polarizing microscope. Small crystals which have not been distorted are optically isotropic, but when bent are feebly birefringent with undulose extinction. The mineral is very tough and sectile. The hardness is $2\frac{1}{2}$. Fragments are readily flattened when pressed with a knife-blade and leave no mark (streak) on paper. The fracture is uneven to sub-conchoidal, and no cleavage could be developed in the directions of the faces of the cube, octahedron or rhombic dodecahedron.

Method of Analysis.—For the analysis only crystallized material was taken, on which no iodyrite could be seen. Any calcite, oxide of iron and native silver were removed by digestion in dilute nitric acid; clayey material and some of the smaller garnets were removed by washing in a stream of water, after which the material was carefully picked out under the lens and examined under the microscope.

In all the analyses the mineral in small fragments was decomposed by means of zinc and sulphuric acid. The silver was collected, washed and dissolved in nitric acid, any insoluble residue (quartz or, in the case of the Broken Hill specimens, minute garnets) being separated at this stage and weighed. The total silver was then precipitated as chloride and weighed. The solution containing the halogens as zinc salts was transferred to a separator and treated with a few drops of a saturated solution of nitrous acid in sulphuric acid. The liberated iodine was dissolved in carbon bisulphide, and the solution collected on a moist filter, washed and titrated with sodium thiosulphate. The sodium thiosulphate solution was standardized by means of pure iodine dissolved in potassium iodide, which was treated in the separator with carbon bisulphide, collected on a filter, and washed in precisely the same way as the iodine solution in the analyses. For the determination of the chlorine and bromine, the indirect method was adopted of precipitating

with silver nitrate, weighing the combined silver chloride and bromide, and then converting wholly into chloride by reducing with zinc and sulphuric acid, dissolving the silver in nitric acid and reprecipitating with hydrochloric acid.

The results thus obtained are given under I, but as a check there are also given under I (*a*) the results of the more indirect calculation of the percentages of the chlorine and bromine from the weights of the total silver and iodine, together with the weight of the mineral used in the analysis. In each case the two results show a fairly close agreement. The atomic weights used were Ag=108, Cl=35·5, Br=80, I=127.

A. Specimen (No. 36280) *from Chañarcillo, Chili.*

The matrix of this specimen is a crystalline limestone which in places is ferruginous, argillaceous, or quartzose, with patches of red hydrated oxide of iron. Embedded throughout are small particles of native silver. Cavities in the mass are lined with crystals of calcite, and on these rest the bright orange-yellow cubo-octahedra of iodembolite, the largest of which are about 7 mm. across. The same cavities also sometimes contain aggregates of small indistinct crystals of pale sulphur-yellow iodyrite, which in places rest upon the orange-yellow cubo-octahedra.

Result of analysis (G. T. P.):—

	I.	I (*a*).
Ag	60·37	60·37
Cl	7·11	6·95
Br	22·35	22·29
I	10·39	10·39
	100·22	100·00
This corresponds to :—		
AgCl . . .	28·72	28·38
AgBr . . .	52·53	52·39
AgI . . .	19·23	19·23
	100·48	100·00

Weight of mineral used = 0·8645 (after deducting 0·0081 insoluble). I = 0·0863; AgCl corresponding to total silver = 0·6949; AgCl + AgBr after separation of iodine = 0·7025; AgCl equivalent to AgCl + AgBr = 0·5950 gram.

Approximate formula: 5AgCl.7AgBr.2AgI.

Specific gravity (weight of 1 cc. at 23° C.)=6·17.

B. Specimen (No. 83825) *from Broken Hill, New South Wales.*

This specimen consists of a large crumbly, but closely set mass of arborescent native silver, the branches of which are encrusted with

bright but minute and indistinct crystals of silver[1]. This is abundantly encrusted with small bright cubo-octahedra of the orange-yellow iodembolite, with which are associated numerous minute reddish garnets, a few angular fragments of quartz sometimes with a bluish opalescence, and a yellow clayey material. Often the crystals of iodembolite are nothing more than hollow shells of material around the native silver, from which the mineral has no doubt been derived. These shells contain in their interior a loose granular aggregate of minute crystals, occasionally distinguishable under the microscope as cubo-octahedra, and, as far as can be seen, with the same characters as the enclosing shells and larger crystals, with which they are no doubt identical. Minute reddish garnets are sometimes completely embedded in the crystals of iodembolite.

This and the following specimens showed no iodyrite in association with the iodembolite, while on almost all other specimens of a similar character from Broken Hill it is present. Usually in these cases the pale yellow iodyrite rests on the darker yellow cubic mineral, though sometimes the reverse is the case.

Result of analysis (G. T. P.):—

	I.	I (*a*).
Ag . . .	56·93	56·93
Cl . . .	1·96	1·70
Br . . .	32·22	32·60
I . . .	8·77	8·77
	99·88	100·00
This corresponds to:—		
AgCl . . .	7·93	7·16
AgBr . . .	75·73	76·61
AgI . . .	16·23	16·23
	99·89	100·00

Weight of mineral used = 0·9311 (after deducting 0·0116 insoluble). I = 0·0816; AgCl corresponding to total silver = 0·7043; AgCl + AgBr after separation of iodine = 0·7789; AgCl equivalent to AgCl + AgBr = 0·6120 gram.

Approximate formula: 5AgCl.40AgBr.7AgI.

Specific gravity (weight of 1 cc. at 18° C.) = 6·31.

[1] These crystals of silver are rarely suitable for goniometric measurement, but on one of them the forms *a* {100}, *d* {110}, and {10.3.0} were determined. The form {10.3.0} does not appear to have been previously recorded on native silver: measured to *a* (100), 16½° to 17°; calculated (100) : (10.3.0) = 16° 42′ (L. J. S.).

C. Specimen (No. 84822) *from Broken Hill, New South Wales.*

This specimen consists almost wholly of a cellular aggregate of greenish-yellow cubo-octahedra of iodembolite. As in the specimen last described these crystals are often only hollow shells of material. The faces of the cube have a drusy or tesselated appearance, owing to the grouping of smaller crystals in parallel position. Brownish garnets occur abundantly embedded in the crystals of the iodembolite. Minute grains of garnet are sometimes aggregated into curious angular forms, of a flesh-pink colour, suggestive of pseudomorphs, or at first sight somewhat resembling crystals of marshite. Psilomelane and limonite are also present in small amount.

Result of analysis (G. T. P.) :—

	I.	I (*a*).
Ag . . .	67·28	67·28
Cl . . .	14·36	14·14
Br . . .	15·85	16·23
I	2·35	2·35
	99·84	100·00

This corresponds to :—

AgCl . .	58·04	57·17
AgBr . .	37·24	38·48
AgI . . .	4·35	4·35
	99·63	100·00

Weight of mineral used = 0·7409 (after deducting 0·0166 insoluble). I = 0·0174 ; AgCl corresponding to total silver = 0·6623 ; AgCl + AgBr after separation of iodine = 0·7059 ; AgCl equivalent to AgCl + AgBr = 0·6406 gram.

Approximate formula : 20AgCl.10AgBr.AgI.

Specific gravity (weight of 1 cc. at 23° C.) = 5·82.

D. Specimen (*No.* 83458) *from Broken Hill, New South Wales.*

This specimen represents what appears to be the commonest type of silver haloid from Broken Hill. It is a large cellular or coralloidal mass, evidently a pseudomorph after wiry native silver, as suggested also by the associations of specimen *B*. The surface of the branches and wires has a drusy aspect, but no definite crystalline form can be distinguished. The colour is pale greenish-grey. The material is tough and sectile. The hardness is $2\frac{1}{2}$. Associated minerals, present in only very small amount, are psilomelane, limonite and small brown garnets.

Result of analysis (G. T. P.):—

	I.	I (*a*).
Ag . . .	66·91	66·91
Cl . . .	13·20	13·18
Br . . .	19·71	19·75
I	0·16	0·16
	99·98	100·00

This corresponds to:—

AgCl . .	53·36	53·28
AgBr . .	46·33	46·43
AgI . . .	0·29	0·29
	99·98	100·00

Weight of mineral used = 1·2565 (after deducting 0·0045 gram insoluble). I = 0·0020; AgCl corresponding to total silver = 1·1170; AgCl + AgBr after separating iodine = 1·2525 gram.

Approximate formula: 3AgCl.2AgBr.

Specific gravity (weight of 1 cc. at 17° C.) = 5·66.

Conclusions.

Collecting together for convenience of comparison the foregoing results, we have:—

	A.	*B.*	*C.*	*D.*
AgCl . . .	28·72	7·93	58·04	53·36
AgBr . . .	52·53	75·73	37·24	46·33
AgI . . .	19·23	16·23	4·35	0·29
Sp. gr. . . .	6·17	6·31	5·82	5·66

These analyses, together with those of other authors, show that the chloride, bromide and iodide of silver can form isomorphous mixtures in very varying proportions. In the case of the chloro-bromides where the limiting members of the series both crystallize only in the cubic (holohedral) system, there is no reason to doubt that isomorphous mixture may take place in any proportion whatever. With the chloro-bromo-iodides the case is different, since the pure iodide, as it occurs in nature and at temperatures below 146° C., is crystallographically distinct from the chloride and bromide. In the latter case it is conceivable that there may be a limit to the amount of iodide which can enter into isomorphous mixture with the chloride and bromide, and that when this limit is passed the excess of iodide will crystallize out as hexagonal iodyrite. In this connexion therefore it is of interest to recall the fact

already mentioned that of the four specimens of iodembolite analysed, iodyrite occurs only in association with the one from Chañarcillo in which the largest percentage of iodine (10·39) was found: iodyrite also occurs in association with the 'iodobromite,' from Dernbach, which contains a still larger percentage of iodine (15·05).

In order if possible to settle this point, some fusion experiments were made with mixtures of silver chloride, bromide and iodide in varying molecular proportions[1], in the same way as that previously employed in the case of miersite (this vol. p. 43). The result of these experiments appeared to indicate that the limiting amount of iodide which could enter into isomorphous mixture with the chloride and bromide was reached for mixtures of the three in about equal molecular proportions (Cl : Br : I = 1 : 1 : 1), for in mixtures containing a less proportion of iodide there was no separation of iodyrite on solidification and cooling after fusion, but in mixtures containing a greater proportion of iodide small specks of doubly refractive iodyrite became more numerous as the proportion of iodide increased.

Sometimes, in the presence of a large excess of silver iodide, fine lamellar intergrowths of isotropic and birefringent material are seen, thus indicating that iodyrite may form intimate intergrowths with holohedral-cubic silver haloid in the same way that it does with miersite (this vol. p. 44). This further implies that at temperatures above 146° C. the amount of iodide which is capable of entering into the isomorphous mixture may exceed to any extent the limit given above. As in miersite, it would thus be possible to have natural crystals of cerargyrite containing an excess of silver iodide as an intimate intergrowth of iodyrite. In none of the natural crystals examined by us is, however, the limit exceeded, for there is no separation of iodyrite when they are fused and again cooled.

The natural crystals of cerargyrite and artificial mixtures in various proportions of silver chloride, bromide and iodide (the last not being in excess), as well as the pure chloride and bromide, all behave in much the same way when fused and again cooled on a microscope slide. They all show the same prominent crystalline structure marked out by two sets of rods and bars, and are isotropic or only feebly birefringent. This fusion method is therefore of no help for purposes of distinguishing the different kinds of cerargyrite.

[1] G. F. Rodwell has determined the specific gravity, melting point and coefficient of expansion of such artificial mixtures (Proc. Roy. Soc., 1876, vol. xxv, p. 292; Phil. Trans., 1883 (1882), vol. clxxiii, p. 1139).

In view of the fact that in the holohedral-cubic silver haloids the chloride and bromide can form isomorphous mixtures in indefinite proportions, and that the iodide can also enter into isomorphous mixture with them in a very varying though limited amount, the present system of classification into a number of arbitrary and apparently disconnected species appears somewhat unsatisfactory. We propose therefore to include all the holohedral-cubic silver haloids under the common group-name of cerargyrite and to use the names 'chlorargyrite,' 'bromargyrite,' 'embolite,' and 'iodembolite' to indicate sub-species depending on varying proportions of chloride, bromide and iodide.

The horny character is common to the whole group, and, as previously mentioned, the name hornsilver was not originally applied merely to the pure chloride, for some of the characters in the older text-books (colour, &c.) attributed to cerargyrite show that at any rate chlorobromides, as well as pure chloride, were included. Portions of these old descriptions, however, appear to have been handed down with too little discrimination, so that they now figure in modern text-books as characterizing the pure chloride. For this reason some of the characters, such as colour and specific gravity, for the sub-species chlorargyrite, embolite and bromargyrite require a certain amount of revision.

As regards colour, the result of the qualitative examination given in the table on p. 177, together with that of the quantitative analyses, suggests that the absolutely pure chloride is colourless or grey, that embolites are mainly greenish-grey, that a decided yellow colour is only apparent when the mineral contains an appreciable amount of iodide, and that when the latter is in large amount (near 20%) the colour is distinctly orange-yellow.

As regards specific gravity, the value 5·552 for chlorargyrite given in the text-books dates back to the time of Mohs (1824). A determination was therefore made of the specific gravity of the pure chlorargyrite, (No. 54819) from the Florida mine, Taltal, Chili, in which the qualitative examination had shown the absence of bromine and iodine. The result of the determination made on 0·6516 gram of material was 5·556 (G. T. P.) as the weight of 1 cc. at 14° C. The specific gravities for embolite, 5·31 to 5·43 of Domeyko, and 5·53 of Yorke, should no longer appear in text-books, as they are obviously too low.

The hardness of 1–1·5 given for chlorargyrite and embolite is too low, for we find that all the specimens which we have examined scratch gypsum with ease, but do not scratch calcite; the hardness is therefore $2\frac{1}{2}$.

The crystal-forms given in the text-books also require confirmation. The forms {211} and {221}, for example, have evidently been copied through Hausmann (1847) from Lévy (1837), who however gives {411} and {441}. On the several crystals examined by us only the cube and octahedron are developed.

The general characters of the Cerargyrite Group may now be summarized as follows:—

Holohedral-cubic. Common forms, the cube, $a\{100\}$, and octahedron, $o\{111\}$. Twinning rare; twin-plane o (111).

Cleavage, none. Fracture, uneven to sub-conchoidal. Tough and sectile. Hardness $= 2\frac{1}{2}$. Specific gravity, variable, depending on chemical composition.

Lustre, resinous to adamantine. Translucent. Colour, variable, and depending on chemical composition, but in all cases altered on exposure to light (differing in this respect from iodyrite and miersite). Optically isotropic.

Chemical composition, Ag(Cl,Br,I), the relative amounts of the isomorphous constituents, Cl, Br and I, varying considerably. On this variation the following *sub-species* are based:—

Chlorargyrite, AgCl. Grey or colourless. Sp. gr. = 5·556.
Bromargyrite, AgBr. Greenish-grey.
Embolite, Ag(Cl,Br). Greenish-grey.
Iodembolite, Ag(Cl,Br,I). Greenish-yellow to orange-yellow.

The results of the present investigation on the silver haloids and a previous investigation by one of us on marshite, miersite and iodyrite (this vol. pp. 38–53. See also p. 188 in this number) show that silver iodide may crystallize under one or other of the following four conditions. At temperatures below 146° C. (assuming atmospheric pressure) pure silver iodide crystallizes as rhombohedral iodyrite, while above this temperature tetrahedral-cubic crystals (type (*b*), this vol. p. 46) are formed: it may also enter, to a certain extent, into isomorphous mixture with holohedral-cubic silver chloride and bromide; or again, with copper iodide, it may form tetrahedral-cubic crystals of the double salt 4AgI.CuI.

The silver haloids at present known to occur as minerals may therefore be classified under the three main species:—

Cerargyrite, Ag(Cl,Br,I), holohedral-cubic.
Iodyrite, AgI, hemimorphic-rhombohedral.
Miersite, 4AgI.CuI, tetrahedral-cubic.

The Identity of Kilbrickenite with Geocronite: and Analyses of Miersite, Marshite, and Copper-pyrites.

By G. T. Prior, M.A., F.G.S.

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[Read February 4, 1902.]

(1) The Identity of Kilbrickenite with Geocronite.

THE mineral kilbrickenite was analysed, described and named by Dr. James Apjohn in 1840[1]. The specimens which he examined were sent to him by Mr. P. M. Taylor, who conducted the mining operations at the Kilbricken mine in County Clare, where the mineral was discovered. Apjohn's analysis showed the presence of lead, antimony and sulphur in proportions corresponding fairly closely with the formula $6PbS.Sb_2S_3$. It was only in the preceding year that L. F. Svanberg had described a new mineral, geocronite[2], to which he assigned the formula $5PbS.(Sb,As)_2S_3$. The announcement of this new mineral appears to have escaped Apjohn's notice, since geocronite is not included in the list of sulphantimonites of lead with which he concludes his paper. Had he been aware of the existence of geocronite, he would probably not have ventured to found a new species on the result of an analysis of a massive mineral differing so little in composition from geocronite, for the numbers in his analysis really correspond to a formula intermediate between $5PbS.Sb_2S_3$ and $6PbS.Sb_2S_3$.

A priori therefore the identity of the two minerals seems highly probable, and in fact, in the earlier editions of Dana's 'System of Mineralogy,' kilbrickenite appears as a variety of geocronite. In later editions, however, and in other text-books the mineral is elevated to the dignity of a separate species.

Recently, through the kindness of Mr. J. J. Beringer, there has been placed at my disposal for analysis material from specimens of kilbrickenite contained in the Museum of the Mining School at Camborne, Cornwall. The genuineness of these specimens is guaranteed by the fact that they form part of the Taylor Collection and are accompanied by two letters, one from Dr. Apjohn to Mr. P. M. Taylor giving the results of his

[1] Proc. Roy. Irish Acad., 1841, vol. i, pp. 469–73.

[2] Kongl. Vetenskaps-Acad. Handl. (for 1839), Stockholm, 1841, p. 184; Ann. Phys. Chem. (Poggendorff), 1840, vol. li, p. 535.

analysis of kilbrickenite, and the other from Mr. P. M. Taylor to Mr. John Taylor stating that he was sending him 'two good pieces of kilbrickenite together with Dr. Apjohn's letter and analysis.'

Physical Characters.—The two specimens of kilbrickenite belonging to the Camborne Mining School are precisely similar in appearance to specimens of massive geocronite in the British Museum from the original locality, Sala, Sweden. They show the same lead-grey colour with metallic lustre, and indications here and there of an imperfect cleavage on which can be seen faint striations in two rectangular directions. The hardness is 3, and the mineral is only slightly brittle. The specific gravity (weight of 1 cc. at 21° C.) of the material used in the analysis is 6·45, practically the same as that of geocronite from Tuscany analysed by Kerndt.

Chemical Composition.—Of the two specimens, one showed some galena in association with the kilbrickenite, but the other appeared to be homogeneous and free from galena. The material used in the analysis was therefore taken from the latter specimen.

The mineral was decomposed in chlorine, the lead was determined as chloride, the arsenic as pyroarsenate of magnesia, and the antimony as sulphide after heating to 260° in carbonic acid. The sulphur was determined in a separate portion by fusion with sodium carbonate and nitre.

Under I is given the result of the present analysis of geocronite ('kilbrickenite') from Kilbricken mine, Co. Clare; under II that of a recent analysis by G. D'Achiardi[1] of crystals of geocronite from Val di Castello, Tuscany; and under III the theoretical composition required by the formula $5PbS.Sb_2S_3 + 5PbS.As_2S_3$.

	I. (Kilbricken).	I. (Atomic ratios).		II. (Val di Castello).	III. (Theoretical).
Pb	68·49	·3318		70·02	69·62
Sb	9·13	·0758	·1370	7·78	8·07
As	4·59	·0612		4·47	5·05
S	17·20	·5376		17·57	17·26
	99·41			99·84	100·00

Weight of material used in analysis = 0·8236. $PbCl_2 = 0.7620$; $Sb_2S_3 = 0.1051$; $Mg_2As_2O_7 = 0.0780$. Weight of material used in sulphur determination = 0·5020. $BaSO_4 = 0.6279$ gram.

The numbers obtained correspond fairly closely with the formula $5PbS.(Sb,As)_2S_3$.

[1] Atti Soc. Toscana Sci. Nat., 1901, Mem. vol. xviii.

The result of the analysis therefore, combined with the correspondence in physical characters, leaves no room for doubt that kilbrickenite is identical with geocronite.

The most important difference between the present analysis and that of Apjohn is the presence of arsenic. In his paper, Apjohn makes no mention of having tested qualitatively for arsenic, nor would his method of quantitative analysis have led to its detection, since he simply precipitated the antimony by sulphuretted hydrogen and weighed the precipitated sulphide after drying at 100°.

The percentage of arsenic (4·59) found in the Kilbricken mineral is very close to that found by Svanberg in the original geocronite from Sala (4·70), and that by Kerndt (4·72) and more recently by D'Achiardi (4·47) in the mineral from Tuscany. This fact that the mineral from three widely different localities contains approximately the same percentage of arsenic lends considerable support to D'Achiardi's suggestion that geocronite is the double salt $5PbS.Sb_2S_3 + 5PbS.As_2S_3$.

It must be pointed out, however, that the acceptation of this idea would necessitate the reference to another species of the 'schulzite' from Meredo, Spain, analysed by Sauvage [1], and the mineral from Björkskogsnäs, Sweden, analysed by Nauckhoff [2], both of which contain no arsenic.

(2) Analysis of Miersite.

Miersite, the new iodide of silver and copper, has been described by Mr. L. J. Spencer in this volume (p. 41). The material, on which the following analysis was made, was collected by him from one specimen (No. 83466) in the British Museum, and was very carefully picked out under the lens and microscope until it showed no trace of impurities.

On this specimen, from Broken Hill, New South Wales, the yellow crystals and crystalline aggregates of miersite rest on a matrix of granular quartz containing copper-glance and a few brown garnets. A little limonite is dusted over the matrix and the miersite, and to remove this the material used in the analysis was digested in warm, dilute nitric acid.

The mineral was decomposed by means of zinc and sulphuric acid. The precipitated silver and copper were dissolved in nitric acid, and the silver determined as chloride and the copper as sulphide. A double precipitation of the copper with sulphuretted hydrogen in fairly acid solution was necessary in order to obtain the sulphide of copper free from zinc. The iodine in solution as zinc iodide in the filtrate from the silver

[1] Ann. des Mines, 1840, ser. 3, vol. xvii, p. 525.

[2] Geol. För. Förh. Stockholm, 1872, vol. i, p. 88.

and copper was liberated by nitrous acid, dissolved in carbon bisulphide, and determined by titration with sodium thiosulphate in the usual way. The following are the results obtained :—

		Atomic ratios.
Ag . . .	38·17	·353 or 4
Cu . . .	5·64	·090 „ 1
I	56·58	·446 „ 5
	100·39	

Weight of mineral used in the analysis = 0·4328; I = 0·2449; AgCl = 0·2195; Cu_2S = 0·0306 gram.

Specific gravity (weight of 1 cc. at 23° C.) = 5·640.

The numbers agree very closely with the formula 4AgI.CuI, to which Mr. Spencer had been led by means of fusion experiments (see this volume, p. 44).

(3) Analysis of Marshite.

Material for the following analysis, free from impurities, was collected from one specimen (No. 84520) in the British Museum by Mr. L. J. Spencer, who has described the physical characters of the mineral in this volume (p. 38).

The marshite on this specimen, from Broken Hill, New South Wales, occurs as numerous fairly large flesh-red tetrahedra (crystals of 'type B,' *loc. cit.* p. 40), encrusting platy psilomelane, which in its turn rests upon an incoherent mixture of cerussite, limonite and garnet with a few bright octahedra of cuprite.

The mineral was decomposed by digestion (several times repeated) with a strong solution of caustic soda. In the residue after filtration the silver was determined as chloride and the copper as sulphide, while the iodine in the soda solution was liberated with nitrous acid and determined by titration with sodium thiosulphate. In the filtrate from the iodine a little copper was precipitated by sulphuretted hydrogen. The following are the results obtained :—

		Atomic ratios.
Cu . . .	32·35	·513
Ag . . .	1·19	·011
I . . .	65·85	·520
	99·39	

Weight of mineral used in the analysis = 0·4808; I = 0·3166; AgCl = 0·0076; Cu_2S = 0·1949 gram.

Specific gravity (weight of 1 cc. at 23° C.) = 5·590[1].

[1] Recently W. Spring (Zeit. f. Anorg. Chem. 1901, vol. xxvii, p. 308) has given

The numbers correspond closely to the formula CuI. The silver is probably due to a slight isomorphous admixture of miersite.

(4) Analysis of Copper-pyrites.

The specimen (No. 63230) of copper-pyrites, the result of the analysis of which is given below, is from Wheal Towan, St. Agnes, Cornwall. It was selected for analysis owing to the peculiarities of its crystals. These, although in other physical respects like copper-pyrites, are in habit apparently cubic and show what seem to be dodecahedral faces. The crystals (measuring about 3 cm. across, and associated with small crystals of quartz and mispickel on a matrix of quartz and chlorite) are so rough and striated that only measurements with the contact goniometer are possible: the angles between the faces intersecting in apparently dodecahedral edges were mostly about 60°. The striations are parallel to the longer diagonal of the rhombic faces, and in the opinion of Mr. L. J. Spencer these crystals are similar to the complex twins of stannite recently described by him in this volume (pp. 54–65) and figured in plate II, fig. 3, i. e. they are probably interpenetrant symmetric twins composed of three individuals with *e* (101) as twin-plane. The appearance of the fractured surface of the crystals, which exhibits a very delicate rippling, is also suggestive of repeated twinning.

In the analysis the copper was determined as sulphide, the iron as oxide, and the sulphur in a separate portion as barium sulphate. The results obtained are:—

		Atomic ratios.
Cu . . .	33·60	·5442 or 1
Fe . . .	30·92	·5533 „ 1·02
S . . .	34·90	1·0912 „ 2·04
	99·42	

Weight of mineral used in analysis = 0·8170; Cu_2S = 0·3520; Fe_2O_3 = 0·3608. Weight used for sulphur determination = 0·4092; $BaSO_4$ = 1·0390 gram.

Specific gravity (weight of 1 cc. at 22° C.) = 4·17.

The result of the analysis shows that the mineral is perfectly pure copper-pyrites, the numbers agreeing very closely with the usual formula $CuFeS_2$. The peculiarities in crystal structure have therefore no connexion with anomalies in chemical composition, nor with any admixture of impurities such as iron-pyrites.

for the specific gravity of precipitated cuprous iodide the value 5·631, as the mean of four determinations, varying from 5·563 to 5·677, made on air-dried, on fused, and also on compressed material.

OBITUARY.

Nils Adolf Erik Nordenskiöld.

The death of Professor Baron A. E. Nordenskiöld at Stockholm, on August 13, 1901, deprives our Society of a distinguished honorary member, elected in 1877 soon after its foundation. His nephew, Dr. Otto Nordenskiöld, writes: 'His death was absolutely sudden: the same day he was working in his laboratory, occupied with great plans in his mineralogical and chemical work.'

Nordenskiöld was born at Helsingfors on November 18, 1832, of a Swedish family possessed of scientific attainments. His father, Dr. Nils Gustaf Nordenskiöld, also well-known as a mineralogist, was director of the Department of Mines in Finland, and the son accompanied his father on many mineralogical excursions, including one to the Urals in 1853. In this way young Nordenskiöld became an enthusiastic student and collector of minerals. In 1849 he entered the University of Helsingfors, applying himself to science and spending his vacations in visiting the rich mineral localities of Finland. His first paper 'on the crystalline forms of graphite and chondrodite,' written in 1855, was a dissertation for the degree of licentiate; in the same year he published his book on the Minerals of Finland, a second edition of which appeared in 1863. Immediately after taking his degree he was appointed Curator of the Mathematico-Physical Faculty and to a post in the Mining Office, but was dismissed in the same year on account of a political speech distasteful to the Russian Government. This rendered it advisable for him to go abroad, and his time was spent working at mineral analysis in Rose's laboratory at Berlin. In 1857 he returned to Helsingfors to take his degree of master and doctor; at the graduation ceremony, which was attended by a deputation from the Swedish Universities, the young doctor again expressed his sympathies too plainly, and as a result was banished from the country.

He then settled in Sweden, and as a geologist accompanied the Swedish expedition to Spitzbergen in 1858. After his return he was appointed professor and director of the mineralogical collections of the State Museum at Stockholm in succession to Mosander. This appointment gave him opportunities for investigating the many rare minerals for which the Scandinavian peninsula is remarkable, and the results of

his work in this direction are recorded in a long list of mineralogical papers. Quite recently, in a paper read before the Geological Society of London, of which he was a Foreign Member, he has given an historical review of Scandinavian minerals containing rare elements. About half of the twenty-six minerals discovered and named by him have withstood the test of subsequent examination, and now rank as well-defined species, of which, among others, may be mentioned crookesite, thaumasite, kainosite, ganomalite, tapiolite, and hydrocerussite. The peculiar borate of calcium and tin, nordenskiöldine, bears his name.

It was, however, as an Arctic explorer that Nordenskiöld achieved fame. He several times visited Spitzbergen, where he made important geological collections. During one of his two expeditions to Greenland he discovered, and brought back in 1870, large masses of the now celebrated Ovifak (Disko) iron, formerly thought to be meteoric, but now known to be of terrestrial origin; he further made important observations on the cosmic dust (cryoconite) which accumulates on the inland ice. During the memorable voyage of the *Vega* in 1878–1880 he accomplished the navigation of the North-East Passage, a feat many times before attempted, thus being the first to circumnavigate Europe and Asia. On his return he received many honours, including a Swedish baronetcy.

NOTES.

The fine private collection of minerals and meteorites, comprising some 10,000 specimens, brought together during a period of thirty-five years by Mr. Clarence S. Bement, of Philadelphia, has recently been purchased by Mr. J. Pierpont Morgan and presented to the American Museum of Natural History at New York. Only shortly before Mr. Morgan had purchased for the same museum, of which he is a trustee, a large collection of precious stones and pearls which was on exhibition by Messrs. Tiffany and Co., of New York, at the Paris Exposition of 1900.

A Mineralogical Society (Wiener Mineralogische Gesellschaft) was founded at Vienna on March 27, 1901. Reports of the monthly meetings, excursions to mineral localities, and visits to museums, will be found in the 'Mineralogische und Petrographische Mittheilungen,' the periodical commenced in 1871 by Professor Tschermak, who is the first president of the new society.

We regret to note the death on July 8, 1901, of Karl Adolf Moberg, who since 1886 has been a member of our Society. He was born at Helsingfors on September 15, 1840, and, after graduating at the University, entered the Government Department of Mines. He was officially connected with the Mint, and for many years was director of the Geological Survey of Finland.

Among other deaths recently announced are:—

Julius Albin Weisbach (1833–1901), who in 1886 succeeded Breithaupt as Professor of Mineralogy in the Mining Academy at Freiberg.

Thomas Egleston (1832–1900), who took an important part in the founding, in 1864, of the School of Mines of the Columbia University at New York, in which institution he was Professor of Mineralogy and Metallurgy until 1897.

C. August Tenne (1851–1901), Docent in the University of Berlin and Curator in the Museum für Naturkunde, Berlin.

Edouard Jannettaz (1832–1900), Assistant in the Mineralogical division of the Natural History Museum at Paris, and past-President of the French Mineralogical Society.

A large octahedral crystal of diamond from the Cape, recently presented to the Natural History Museum at Vienna by Georg von Haas, was described by Professor F. Berwerth in Band xix (1900, p. 340) of Tschermak's 'Mineralogische und Petrogr. Mittheilungen.' It weighs 82·5 Vienna carats, and in the direction of the axes the dimensions are from 2·4 to 2·8 centimetres; and it was thought by Professor Berwerth to be the largest crystal of diamond exhibited in any public collection. It may, however, be noted that the 'Colenso' diamond, presented to the British Museum (Natural History) by John Ruskin in 1887, weighs $129\frac{2}{3}$ carats.

A selection from a large series of well-crystallized minerals, mainly calcite and barytes, from the haematite mines of West Cumberland, is at present exhibited in the recent acquisition case in the Mineral Gallery of the British Museum at South Kensington.

Professor R. Brauns, in a recent number of the 'Centralblatt für Mineralogie, &c.' (1901, p. 134), points out that the characters given for conchite, a supposed new modification of calcium carbonate described in this Magazine (vol. xii, p. 363), are sufficiently close, considering the unsatisfactory nature of the material available for examination, to those of aragonite to suggest the identity of conchite with that species. The

same conclusion has been independently arrived at by Professor H. Vater (Zeits. Kryst. Min., 1901, vol. xxxv, p. 149), who further gives reasons for considering that ktypeite also is probably identical with aragonite.

A new issue (fourth thousand) has been received of Professor A. H. Church's useful and well-known little Handbook on Precious Stones. Except for one or two minor alterations, the text remains the same as before, but two pages of supplementary notes are given at the beginning of the volume.

We have received from Mr. H. Y. L. Brown, F.G.S., the Government Geologist of South Australia, various reports and a Handbook of Mining which have been issued for free distribution by the Department of Mines. The Handbook of Mining gives a brief account of the mineral resources of the State, together with a summary of the Mining Acts and regulations, and it is accompanied by four large maps showing the distribution of metallic minerals. From the same source we have also received an excellent geological map of South Australia on a scale of 16 miles to the inch.

REVIEW.

The Mineralogy of Scotland. By the late M. Forster Heddle, M.D., F.R.S.E., Emeritus Professor of Chemistry, St. Andrews. Edited by J. G. Goodchild, H.M. Geological Survey, F.G.S. Two vols. (pp. lviii and 148, viii and 247, 30 text-figs. and 120 plates). Edinburgh: David Douglas. 1901. (Price 36*s. net.*)

These two handsome volumes form a fitting memorial to Professor Heddle, so well known for the enthusiasm and energy with which for many years he studied the minerals of his native country. No one was better acquainted with the mineral localities of Scotland, nor has any one laboured more assiduously at the chemical analysis of Scotch minerals. The many papers, some of great length, published in the pages of this Magazine, are sufficient testimony to his ceaseless activity in this direction. For many years he had been collecting material which some day he hoped to publish as a connected whole, but at his death[1] in 1897 this work was unfortunately still incomplete. In handing over his voluminous notes and drawings to his son-in-law, Mr,

[1] For an obituary notice of Dr. Heddle see this Magazine, vol. xii, p. 38.

Alexander Thoms, Heddle expressed the wish that they should be published as a book, and the laborious work of editing this material has been ably performed, considering the difficult nature of the task, by Mr. J. G. Goodchild. This has been done with as little alteration as possible, the aim of the editor being to complete the work as Heddle would himself have done. In this work of completion free use has been made of the large collection of Scottish minerals brought together and arranged by Heddle himself, and now under the charge of Mr. Goodchild in the Edinburgh Museum of Science and Art.

In addition to the main part of the work, for which Mr. Goodchild is responsible, Mr. Thoms contributes a memoir of Dr. Heddle, as well as lists of minerals found in each of the counties of Scotland, while Mr. James Currie gives (vol. i, pp. xxxvii–l) a very complete and useful list of Scottish pseudomorphs, with the localities at which they have been found.

The bulk of the volumes is occupied by particulars of the occurrence of just over 200 mineral species in Scotland. Every locality at which each species has been found is enumerated, and in each case is stated the kind of rock in which the mineral occurs, and the other species with which it is associated, together with a brief description of the mineral itself, including in most cases the combinations of forms observed on the crystals. For information concerning Scottish mineral localities, this treatise far surpasses anything hitherto attempted, and it will long remain a standard work of reference. Mr. Goodchild has greatly added to its value in this respect by a very full synonymic index of locality names, in which he has been at great pains to give the exact situation of each place; the various mineral species found at each locality are also enumerated.

While the topographical portion is very complete and of much value, that dealing with crystallography is less satisfactory. Here the editor has been at a disadvantage owing to the different systems of notation employed by Heddle at various times, and apparently because of the incomplete state in which this portion was left at the author's death. Whether the numerous forms have been determined by mere inspection of crystals or by actual goniometric measurement does not appear to be stated; at any rate for only a few species are tables of *calculated* angles given, these being in some places the face-angles and in others the normal-angles. Under calcite is given a long list of 266 forms, which surely have not all been observed on Scotch crystals of this mineral. To the crystallographic portions Mr. Goodchild has added several beautiful

plates giving stereographic or gnomonic projections for the more commonly occurring crystallized species. These, though excellent in themselves, are open to the same objection as is the list of forms of calcite noted above, since in representing all the forms known for each species they seem rather out of place in a 'Mineralogy of Scotland.'

The most striking feature of the volumes is the 120 excellent plates, one of which is a portrait of the author; most of the others contain eight figures of crystals, beautifully and clearly drawn. In the preface we find the statement that 'The author died before making a final selection of the illustrations, and it has therefore been deemed advisable to have these all engraved just as they left his hands, even though some of them appear to have been taken from other sources.' There is thus no guarantee that all of these numerous figures refer to Scottish crystals, and it is possible that some of them may have been drawn by the author to illustrate an account of minerals in general, as for example his article on Mineralogy in the ninth edition of the 'Encyclopædia Britannica.' Several of the figures seem familiar; some of those of chalcopyrite, for example, are exact copies of Haidinger's figures of Cornish crystals.

In many cases very little account is taken of the work of other authors except as far as regards occurrences and chemical analyses; and the descriptions of some typically Scotch minerals, for example, greenockite, are consequently rather disappointing.

In works of this kind errors and omissions are almost unavoidable, and the present is by no means an exception in this respect. The way in which Dana has been rigidly followed has led to one or two curious mistakes. The only index of mineral names includes also those of minerals not found in Scotland, and is unfortunately not accompanied by references to pages. In the absence of any list of the abbreviations and signs of various kinds which are made use of, it is not always easy to discover their meaning.

ABSTRACTS.

Constitution of Silicates (W. Vernadsky, Zeits. Kryst. Min., 1901, vol. xxxiv, pp. 37–66).—In this contribution to the study of the theoretical constitution of silicates the author first points to the analogy between the part played by carbon in organic chemistry and the part played by silicon in mineralogical chemistry. Admitting that the investigations of the latter have not led at present to results which

justify a fully developed theory, he puts the conclusions from collected data into the form of a suggestion towards the solution of the problem of the constitution of natural silicates.

For his present purpose the author puts aside certain silicates (amongst them those containing haloids and metalloids) as not admitting at present of conjectural structural formulae, and deals only with silicates which may be regarded as isomorphous mixtures consisting of Si, O, H, and metals. He calls the *principal* constituent of such an isomorphous mixture (and to which he attributes his structural formula) the 'Lösungsmittel.'

He divides the silicates under consideration into two classes :—

I. Those containing no metal-oxide of the type $R_2'''O_3$. These he calls simple silicates.

II. Those containing such a metal-oxide. These he calls alumosilicates (ferro-, chromo-, &c., according to their composition).

Among the reasons for the sharp distinction between these classes, the following are alleged. There is no transition from one to the other so far as the 'Lösungsmittel' is concerned. A metal of the oxide RO is never replaced by aluminium. The weathering of class I gives hydrated silica and silica, while the weathering of class II rarely gives hydrated silica, and generally gives clays and chloritic minerals. Class I can *always* be regarded as salt or hydrate, or some more or less complicated addition product of salts or hydrates of a *known* silicic acid, while it is difficult to reconcile class II with any known or conceivable silicic acid or hydrate. The writer gives reasons for regarding class II rather as anhydride, hydrate or salt (and their various derivatives or addition products) of complex alumosilicic acids.

Class I is divided into subdivisions which the writer formulates thus :—

(i) Hydrates. Represented by opal (group 1).

(ii) Orthosilicates, $(RO)_2 = Si = (OR)_2$, represented by the olivine group (salts) (2), sepiolite (acid salt) (3), and various minerals of which he takes chondrodite (4), serpentine (5), chrysocolla (6), noumeaite (7), and calamine (8) as typical, which are all called addition products of orthosilicates.

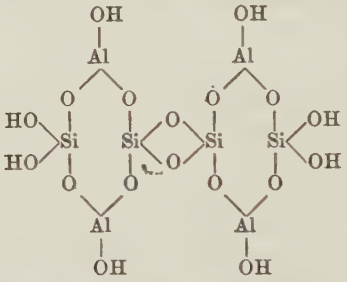
(iii) Metasilicates, $(RO)_2 = Si = O$. Represented by the pyroxene and amphibole groups (9), talc (acid salt) (10), and apophyllite (addition product ?) (11).

Attention is called to the separation of gelatinous silica from the orthosilicates, of powdery silica from the metasilicates, and of 'slimy' silica where the mineral can be regarded as a mixture of both.

Class II is subdivided as follows:—

(i) Complex anhydrides and their addition products. Represented by the sillimanite group (12.).

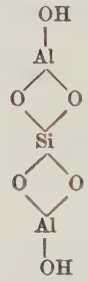
(ii) Complex acids and hydrates and their addition products. Represented by the kaolin group (13), to which the writer attributes the following structure, which will be noticed to resemble an addition product on the 'mica type' noticed below.



$(H_2Al_2Si_2O_8 . H_2O$, Kaolin).

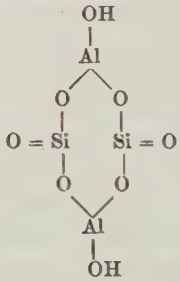
(iii) Complex salts and addition products; in which the writer recognizes two types:—

Chlorite type.



$(RO . Al_2O_3 . SiO_2)$

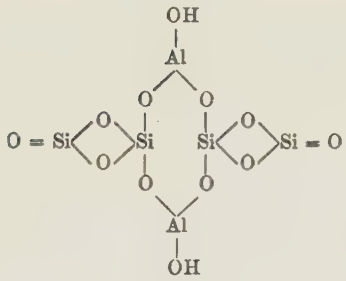
Mica type.



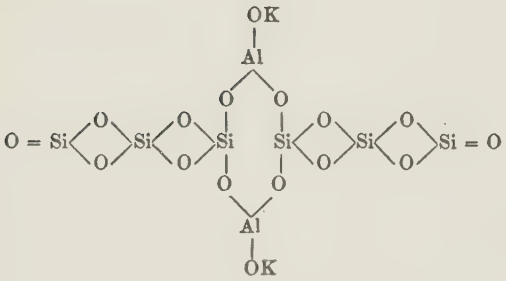
$(M_2O . Al_2O_3 . p\,SiO_2$, where $p = 2, 4, 6$, etc.)

The chlorite type is represented by staurolite (14), various minerals of which he takes clintonite (15), chlorite (16) as typical addition products, and melilite (17) (classed as doubtful).

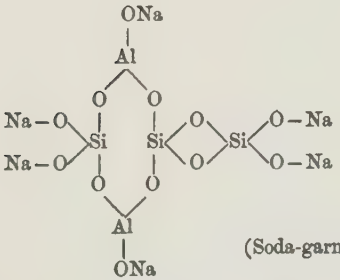
The mica type is represented by the mica group (18), and various minerals which represent addition products, and of which the writer takes the following as typical: leucite (19), felspar (20), petalite (21), nepheline (22), carpholite (23), scapolite (24), epidote (25), garnet (26), vesuvianite (27), prehnite (28), cordierite (29), and zeolites (30). For these the following structural formulae are given:—



(Leucite)



(Felspar.)



(Soda-garnet = lagoriolite.)

The writer completes his classification by adding to his simple silicates (A) and alumosilicates (B), to which he attributes structural formulae as above, the following classes which he does not undertake at present to describe by a graphic structure, viz.:—beryllium silicates (C), borosilicates (D), cerium and yttrium silicates (E), titanosilicates (F), zirconosilicates (G), and uranosilicates (H). W. P. B.

The Structure of Crystals: Part I, Report on the Development of the Geometrical Theories of Crystal Structure, 1666–1901. (Drawn up by W. Barlow and H. A. Miers, assisted by G. F. Herbert Smith. British Association for the Advancement of Science, Glasgow Meeting, 1901, Section C. 41 pp.)—In this Part is considered the manner in which the

material constituting the crystal is put together; a side of the subject which seems to have reached something like finality. The historical development of the subject is sketched, and the more important contributions are discussed in detail. Early speculations that the forms of crystals may be imitated by the packing together of similar bodies, Steno's observation of the identity of the mutual inclinations of corresponding faces of rock-crystal in different specimens, and Romé de l'Isle's important discovery, that the various shapes of a crystal may all be deduced from the same primitive form, lead up to the epoch-making writings of *Haüy*. From the phenomena of cleavage he deduces that crystals are built up of a regular accretion of the ultimate parts, *molécules intégrantes*, immediately derivable from the cleavages of the substance. Secondary faces are supposed to be due to the deposition of successive layers on each face of the original nucleus to form regular steps, so that their boundaries form planes which truncate the edges or corners of an enlarged figure due to a uniform growth of the nucleus. In cases where the *molécules intégrantes* are not parallelepipeda, Haüy regards them as aggregated to form parallelepipedal groups, *molécules soustractives*, which, however, are merely geometrical conceptions to elucidate the growth of secondary faces and may be only fictions. This regular growth of secondary faces leads at once to the great Law of the Rationality of Intercepts, more familiarly known as the Law of Rational Indices. His theories are not free from objection; nevertheless they place the study of crystal structure on a sure foundation. His *molécules intégrantes* are especially interesting in the light of later research, since they reduce the problem to the partitioning of space into similar polyhedra which are not necessarily parallel.

The importance of Haüy's law of rational indices was speedily recognized. Weiss and Mohs employed it to place in a clear light the ascertained facts regarding the outward form and the optical properties of crystals. Hessel in a remarkable work, which remained overlooked for sixty years, showed that this law limits the number of possible types of crystals to thirty-two. Nearly forty years later Gadolin came independently to the same result by similar reasoning. This method leads to a curious case of pseudo-trigonal symmetry which has attracted some attention.

All the writers immediately subsequent to Haüy disregarded the shape of the constituent particles and confined their attention to their centres, which they supposed to be arranged on a parallelepipedal network or space-lattice. In this simple guise the problem was discussed by

Frankenheim. Rigid proofs of his geometrical investigations were supplied by *Bravais*, who also considered the effect of the individual symmetry of the units on that of the whole structure. He employed the mathematical conception of a coincidence-movement, and virtually studied the possible varieties of axes of symmetry, and the possible ways in which they can exist in a system whose various parts can be derived from each other by movements of translation. He found fourteen different lattices (Frankenheim gave fifteen, but two are really identical). Bravais explains hemihedrism as due to the symmetry of the constituent unit, and employs the phenomenon of cleavage as a clue to the internal symmetry. Bravais marks a very important epoch: the knowledge of the properties of the space-lattice first provides a single principle capable of explaining at the same time the law of rational indices, the homogeneity of a crystal, and the main features of crystalline symmetry.

A most important departure is marked by Wiener, who laid down the principle that regularity in the arrangement of identical atoms is presented when every atom has the remaining atoms arranged about it in the same manner; thus no longer laying stress on sameway orientation. Jordan in a mathematical paper discussed the general problem of groups of movements. This is of vital importance in studying the manner in which the various parts of a structure are symmetrically related to each other; one being derived from another by an imaginary movement. In his influential works *Sohncke*, employing Wiener's principle and Jordan's method, obtains what he calls 'a regular point system.' He introduces screw-movements, which may be said to result in two interpenetrating congruent lattices, and finally arrives at sixty-five different systems. As far as it goes his method is complete, but, as Wulff pointed out, it fails to account for the symmetry displayed by dioptase, and he is, like Bravais, driven to make the symmetry of a system depend partly on the arrangement of the ultimate parts and partly on the configuration of these parts.

The introduction of the principle of mirror-image repetition marks the last great advance in the development of the geometrical theory. The credit is shared by Curie, Schönflies, and Fedorow. The first named, however, only applied it to the derivation of the thirty-two classes of central symmetry. Schönflies and Fedorow arrived independently at the 230 groups of crystal structure, in which all the thirty-two classes are represented. *Schönflies* shows that any homogeneous arrangement has the elements of symmetry of one of these classes, and may at the same time be referred to one of the translation

groups, or space-lattices. By applying these methods and determining which of the resulting groups are identical, he finally arrives at the number mentioned. The later part of his great work, 'Krystallsysteme und Krystallstructur,' is occupied with the question of space-partitioning. He discusses at length the 'elementary cell,' which is such that all the elements of symmetry lie on its surface; if repeated about certain of these elements a symmetrical space-unit, the 'complex cell,' is obtained. A corresponding crystalline structure is derived by furnishing each elementary cell in a similar manner with contents of any nature. *Fedorow* adopted similar reasoning but somewhat different analytical methods. He studied the symmetry of finite solid figures in general, and, limiting the problem by a condition equivalent to the law of rational indices, obtains the thirty-two classes. In a later memoir he shows that space may be filled by parallelohedra or by stereohedra, which are identical or symmetrical figures, not necessarily parallel. When space is partitioned into differently orientated identically similar plane-faced stereohedra, these may be grouped together into sets, such that each set is a parallelohedron; further, the analogous points of the stereohedra constitute a regular point-system, just as the analogous points of the parallelohedra constitute a space-lattice. In his second treatise he deals with regular systems of figures and more directly approaches the problem of crystal structure. His definition is practically the same as that of Schönflies, and necessarily results in 230 groups; he also arrives at the 'elementary cell.' *Barlow* attacked the problem in a different manner. Proceeding from structures of lower to those of higher symmetry, he obtains Sohncke's sixty-five sets of coincidence-movements, and points out that to each of these corresponds a class of homogeneous structure which is not identical with its own mirror-image. From each of these groups he develops, where possible, others by repetition across centres of symmetry, planes of ordinary or gliding symmetry, and axes of alternating symmetry (the Sohncke axes remaining unchanged), and finally obtains 165 additional groups, giving 230 in all.

Kelvin has considered the problem of crystal structure mainly on the basis of the space-lattice, and arrived independently at the tetrakaidekahedron (Fedorow's heptaparallelohedron) as the most general form of cell belonging to a homogeneous space-partitioning. In the 'Boyle Lecture,' published in 1894, he discusses the relationship between the three aspects of the problem, namely, homogeneous assemblages of points, partitioning of space, and close-packing of similar bodies.

In a subsequent Part it is proposed to discuss the various mechanical and physical conceptions which have been employed, and the definite structures ascribed to certain substances. G. F. H. S.

Optical Determination of Ores (J. Koenigsberger, Centralblatt Min., 1901, pp. 195–7).—Light reflected normally from the surface of an anisotropic substance becomes polarized to a small extent, while from an isotropic substance there is no polarization of the light. It is proposed to make use of this fact for distinguishing opaque minerals under the microscope, e. g. pyrites from marcasite, or magnetite from haematite. A bright crystal face or a cut and polished surface is illuminated by a vertical illuminator (a right-angled prism) inserted in the tube of the microscope above the objective, and any polarized light is detected by a Savart's plate and analysing nicol also placed in the tube of the microscope. The eye-piece of the microscope is replaced by a small telescope, and artificial light is used for illumination, since daylight is already partly polarized. Anisotropic crystals will then give rise to interference fringes, which will disappear and attain a maximum four times in a complete revolution of the microscopic-stage; and what corresponds to extinction angles in transparent crystals can be measured. If the crystal happens to be cut perpendicular to an optic axis no fringes will be seen unless the plate be tilted, when the difference between an isotropic and an anisotropic crystal can be seen on rotating the stage. Theoretically it is also possible to distinguish between uniaxial and biaxial crystals, but this would be difficult in practice. L. J. S.

The Stereographic Projection and its possibilities from a Graphical Standpoint (S. L. Penfield, Amer. J. Sci., 1901, ser. 4, vol. xi, pp. 1–24, 115–44, with 4 plates and 34 text-figures; also in part in Zeits. Kryst. Min., 1901, vol. xxxv, pp. 1–24).

The author points to the advantages, especially from an educational point of view, of solving crystallographic and other problems involving spherical trigonometry by graphical methods based on the principle of the stereographic projection. This method, although capable of a fair degree of accuracy, cannot of course take the place of exact numerical calculations, but it gives an easy means of checking results so obtained. It is also pointed out that for geographical maps and charts the stereographic projection would be much better than the incorrect methods of projection now in use, namely, the globular and Mercator's.

For the purpose of accurately plotting and taking measurements from

stereographic projections the following mentioned protractors and scales have been designed and constructed:—

'Protractor No. I,' with stereographically projected degrees on the base-line, for plotting stereographic projections.

'Stereographic Protractor No. II,' with small vertical circles at every degree, for measuring the arcs of great circles.

'Stereographic Protractor No. III,' with great and small circles at every fifth degree.

'Stereographic Protractor No. IV,' with great circles at every alternate degree.

Protractor No. I is printed on cardboard, and the others are printed on thin sheets of celluloid so that they can be laid over the drawing for taking measurements. The complete set, which is patented in the United States and is placed on the market, includes sheets of drawing paper on which are printed a graduated circle, scales giving the radii of stereographically projected arcs of great circles and of small vertical circles, and scales of decimal parts and of stereographically projected degrees; also sheets printed with equatorial and meridian stereographic projections for map-drawing. All the scales, &c. are for a circle 14 cm. in diameter. For drawing the arcs of great circles of large radii a curved ruler is needed, of which a new form is figured and described. Points on the drawing are accurately located by a needle-point held against a half lens mounted on a stand. Finally, a set of instruments for blackboard demonstration is described.

In the original paper seven special cases are taken to illustrate the solution of spherical triangles, both right-angled and oblique, by graphical methods. The errors in the results obtained in these cases amounted to from 1′ to 15′, and on the average were only about five minutes.

L. J. S.

Pyrites and Marcasite (H. N. Stokes, Bull. U.S. Geol. Survey, 1901, No. 186, 50 pp.; Amer. J. Sci., 1901, ser. 4, vol. xii, pp. 414–20; Chem. News, 1902, vol. lxxxv, pp. 33 et seq.).—When pyrites and marcasite are not distinctly crystallized it is often difficult to distinguish between them, and the characters usually relied on for this purpose, namely colour, specific gravity, and ease of oxidation, are not altogether trustworthy. It is pointed out that the true colour of marcasite is tin-white, and that the usual bronze-yellow is due to tarnish.

The author has devised a chemical method for the discrimination of these minerals, and for their quantitative determination in mixtures.

This method depends on the fact that when pyrites or marcasite is boiled with an excess of a solution of a ferric salt to complete reduction of the latter, the ratio of sulphur oxidized to mineral decomposed is perfectly definite and characteristic of each mineral, provided certain standard and easily controllable conditions are observed. With a boiling solution of iron ammonium alum containing 1 gram of ferric iron and 16 cc. of 25 per cent. free sulphuric acid per litre, the percentage of sulphur oxidized in pyrites is about 60·4, and in marcasite about 18 per cent. of the total sulphur. These figures are the characteristic oxidation coefficients, which depend, however, on the temperature and concentration of the solution. The determinations are made in an atmosphere of carbon dioxide, with specially designed apparatus.

An empirical curve for the oxidation coefficients of mixtures of pyrites and marcasite in known proportions gives a means of quantitatively determining the composition of naturally occurring mixtures. In this way it was shown, for example, that the nodules, often supposed to be marcasite, so abundant at Folkestone, are really pyrites; one specimen was found to contain pyrites 97, and marcasite 3 per cent.; and a pyritized ammonite, also from Folkestone, consisted of pyrites 88, and marcasite 12 per cent. L. J. S.

New Minerals from the Binnenthal Dolomite. The mineral sulpharsenites known to occur in the white crystalline dolomite of the Binnenthal, Switzerland, include sartorite ($PbS.As_2S_3$), rathite ($3PbS.2As_2S_3$), dufrenoysite ($2PbS.As_2S_3$), jordanite ($4PbS.As_2S_3$), and tennantite ($3Cu_2S.As_2S_3$, 'binnite'). To this list three more new minerals have recently been added, one of which, *baumhauerite*, is described by R. H. Solly in the present number (p. 151).

Seligmannite (H. Baumhauer, Sitz.-ber. Akad. Wiss. Berlin, 1901, pp. 110–7).—Of this mineral, named after Herr G. Seligmann of Coblenz, only five crystals, varying in size from ½ to 4 mm., have been found, and it has been possible to make only a crystallographic examination. The colour, lustre, and brittleness are like those of the other Binnenthal sulpharsenites. In the habit of the rhombic crystals, in the forms present, the interfacial angles, and the repeated twinning on both prism planes (110), the mineral is closely allied to bournonite, with which it is no doubt isomorphous, being possibly the corresponding arsenic compound, $Cu_2S.2PbS.As_2S_3$.

Seligmannite, $a:b:c = 0{\cdot}92804:1:0{\cdot}87568$
Bournonite, „ $= 0{\cdot}93798:1:0{\cdot}89688$.

Liveingite (R. H. Solly, Proc. Cambridge Phil. Soc., 1901, vol. xi, pp. 239–40).—Of this mineral, named after Prof. G. D. Liveing of Cambridge, only two crystals have been found, and the greater part of these have been used for a chemical analysis. The crystals are oblique, with a pseudo-rhombic habit; in the development of the dome zone there is a resemblance to rathite, while in the oblique prism zone ($\beta = 89° 45\frac{1}{2}'$) there is a resemblance to sartorite. The crystals are twinned on the orthopinacoid (100), and the two individuals are tarnished respectively green and red. Analysis by H. Jackson gave the following results:—

	Liveingite.	$4PbS.3As_2S_3$.	$5PbS.4As_2S_3$.
Pb . .	47·58	48·75	47·44
S . .	24·91	24·61	25·00
As . .	26·93	26·64	27·56
Fe . .	trace		
	99·42	100·00	100·00

In the original paper the formula is given as $4PbS.3As_2S_3$, but, as noted elsewhere (this number, p. 160), the results are in closer agreement with $5PbS.4As_2S_3$. L. J. S.

A simple Reaction for distinguishing Aragonite and Calcite (W. Meigen, Centralblatt Min., 1901, pp. 577–8).—The finely powdered material is placed in a dilute solution of cobalt nitrate, and this boiled for a few minutes. In the presence of aragonite there is formed a lilac-red precipitate of basic cobalt carbonate, while calcite remains white, or, in the presence of organic matter, becomes yellowish. Barium and strontium, but not magnesium, carbonate give the same result as aragonite, and calcium phosphate produces a blue precipitate. This reaction is made use of for the purpose of distinguishing calcite and aragonite in various animal and vegetable secretions of calcium carbonate.

These experiments have been repeated by G. Panebianco (Rivista Min. Crist. Italiana, 1902, vol. xxviii, pp. 5–12), who with Iceland-spar obtained a lavender-blue powder having the composition $CoCO_3 + \frac{3}{10}H_2O$, and with aragonite from Herrngrund a violet powder with the composition $CoCO_3 + \frac{1}{10}H_2O$.

This difference in behaviour of calcite and aragonite is the subject of some remarks of a theoretical nature by G. Wyrouboff (Bull. Soc. franç. Min., 1901, vol. xxiv, pp. 371–3). He attributes the greater stability of the physical particles of calcite to the higher degree of symmetry possessed by this mineral. L. J. S.

Minerals of Roumania (P. Poni, Ann. Sci. Univ. Jassy, 1900, vol. i, pp. 15–148).—A systematic description is given of all the mineral species known from Roumania, with notes on their occurrence at various localities. The paper is in French, and quotes much information from the somewhat inaccessible Roumanian journals. Several chemical analyses are given, and structural formulae are discussed, but there are no crystallographic descriptions. Two massive minerals are described under the new names badenite and brostenite: the former is considered to be a bismuthal variety of smaltite (or safflorite) with the formula $(Co,Ni,Fe)_2(As,Bi)_3$; the latter a hydrated manganite of iron and manganese of variable composition. L. J. S.

Cleopatra's Emerald Mines (D. A. MacAlister, Geographical Journal, 1900, vol. xvi, pp. 537–49).—An account is given of an expedition made in 1899 to the ancient emerald mines in the Jebel Sikait district (Northern Etbai), which is situated about 15 miles from the Red Sea in latitude 24° 40′ N. [The locality usually given in mineralogical text-books is Jebel (= Mount) Zabara, Zebarah, or Sabara, &c., in the Ababdeh desert, Egypt. This is about ten miles to the north of Jebel Sikait.] There are several scattered groups of primitive workings belonging to different periods dating back 2,000 years, and in the desert region are ruins of houses, temples, &c. The rocks of the district are gneisses and schists; the old mines are all in mica-schist or talc-schist. L. J. S.

Association of Epidote and Zoisite (P. Termier, Bull. Soc. franç. Min., 1900, vol. xxiii, pp. 50–64).—A case is described of the occurrence together of the trimorphous minerals epidote, α-zoisite and β-zoisite (see Abstract, Min. Mag. xii. 215). The 'green rocks' of Mount Pelvas (or Paravas), on the Franco-Italian frontier, contain veins and patches of white prehnite in which are embedded prisms of pale-green epidote and fine needles of very pale rose-coloured zoisite. The zoisite has the optical characters of α-zoisite, but sometimes a little β-zoisite is intergrown with it. At times there are also regular intergrowths of epidote and zoisite, with a definite crystallographic orientation between the two minerals: this indicates that the crystalline structures of epidote and zoisite must be closely related. L. J. S.

Synchysite, a new Mineral allied to Parisite (G. Flink, Bull. Geol. Inst. Univ. Upsala, 1900 (1901), vol. v, pp. 81–7).—This mineral, from Narsarsuk in South Greenland, discovered and analysed by

G. Nordenskiöld in 1894, and again examined by Flink in 1900 (this vol. p. 94, abstract), has previously been referred to parisite, since in its characters it agreed to a certain extent with the parisite of Muso, Colombia. The true characters of the Muso parisite were, however, somewhat doubtful until recently, when S. L. Penfield and C. H. Warren (Amer. Journ. Sci., 1899, ser. 4, vol. viii, p. 21), in connexion with their description of the newly discovered parisite from Ravalli County in Montana, made a new analysis of the Muso mineral. The latter results prove that the Greenland mineral differs from parisite, and for it the new name synchysite (*συγχυσις*, confounding) is now proposed. The following are the main characters which distinguish the two species :—

	Synchysite.	Parisite.
Chemical formula .	$CeFCa(CO_3)_2$	$(CeF)_2Ca(CO_3)_3$
Cleavage . . .	None original	Distinct basal
Sp. gr. . . .	3·902	4·364
Refractive indices .	ω 1·6742	1·569
	ϵ 1·7701	1·670
Crystal-system . .	Rhombohedral	Hexagonal

In general appearance and in some other respects the two minerals are, however, very similar, and the crystal-forms of synchysite can be referred to the axes of parisite. L. J. S.

Selenium Minerals from the Skrickerum mine, Sweden (E. Svedmark, Teknisk Tidskrift, 1899; abstract in Zeits. Kryst. Min., 1901, vol. xxxiv, p. 693).—The Skrickerum mine in the parish of Tryserum, government Kalmar, Sweden, is noted for the selenium minerals, eucairite (CuAgSe), berzelianite (Cu_2Se), and crookesite ($(Cu,Tl,Ag)_2Se$), which it has yielded, and it was from here that Berzelius in 1818 described the first mineral found to contain this element. The mine was worked only from 1779 to 1784 for copper ores, and all the previous mineral finds were made on the old heaps of mine refuse. Recently (1898) the mine has been opened up again, by a party of mineral collectors, for the rare selenium minerals, which occur in a small calcite vein. The berzelianite is present as a dusty impregnation in the calcite, and varies in amount from a trace to ten per cent., averaging about three per cent. of the whole mass. Eucairite, as silver-white to blue-grey, malleable grains, is of rarer occurrence. Associated minerals are :—native silver and copper, cuprite, several iron silicates, carbonaceous pitchblende, uranium ochre, &c.

L. J. S.

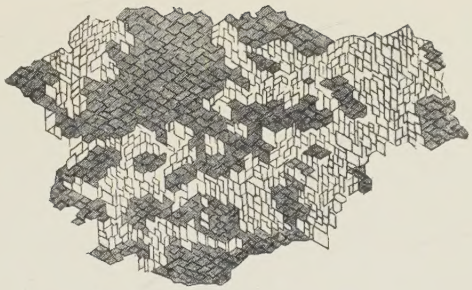


Fig. 1.

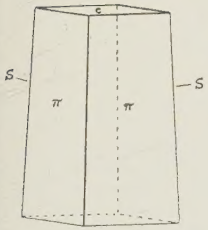


Fig. 2.

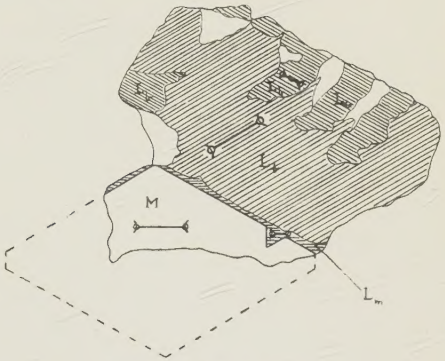


Fig. 3.

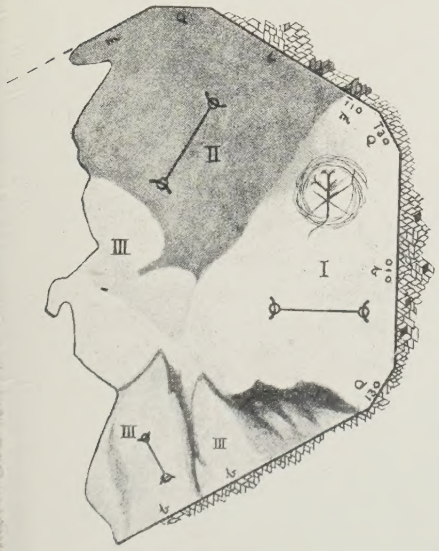


Fig. 5.

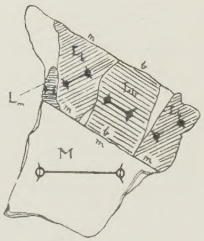


Fig. 4.

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